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JOURNAL OF ANATOMY AND PHYSIOLOGY

CONDUCTED BY SIR WILLIAM TURNER, K.C.B., M.B., LL.D., D.C.L., D.SC., F.R.S., PRINCIPAL OF THE UNIVERSITY OF EDINBURGH; D. J. CUNNINGHAM, M.D., D.SC., LL.D., D.C.L., F.R.S., PROFESSOR OF ANATOMY IN THE UNIVERSITY OF EDINBURGH; G. S. HUNTINGTON, A.M., M.D., PROFESSOR OF ANATOMY, COLUMBIAN UNIVERSITY, NEW YORK; A. MACALISTER, M.D., LL.D., D.SC., F.R.S., F.S.A., PROFESSOR OF ANATOMY IN THE UNIVERSITY OF CAMBRIDGE; AND J. G. M'KENDRICK, M.D., LL.D., F.R.S., PROFESSOR OF THE INSTITUTES OF MEDICINE IN THE UNIVERSITY OF GLASGOW

VOL. XL.

THIRD SERIES—VOLUME I.

WITH PLATES AND ILLUSTRATIONS IN THE TEXT

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PREFACE TO THE FORTIETH VOLUME.

In November 1866, the first number of the *Journal of Anatomy and Physiology* was published. To-day we issue the first part of our fortieth volume, and we make it the commencement of our third series. Prior to 1866, no Journal specially devoted to Anatomy and Physiology had been published in this country. The Transactions and Proceedings of Royal and other learned Societies, and the medical Journals and Reviews, had been almost the only media through which anatomists and physiologists had been enabled to make their researches known. Between the years 1861–5, however, the *Natural History Review*, a quarterly Journal of Biological Science, edited by distinguished naturalists, had been the channel through which a number of papers on human and comparative anatomy had been made public; but in the last-named year this Journal ceased to appear.

It was therefore felt by some of the younger anatomists, that, owing to the increasing number of workers in Anatomy and Physiology in the United Kingdom and the greater attention paid to these branches of science in our Universities, the time had come when a Journal, which might offer a ready medium for the publication of original matter, and which, by giving Reports on the progress of these sciences, might enable anatomists and physiologists in Great Britain and Ireland to be cognisant of the researches that were being made in this and other countries, would supply a want. In the prospectus of the first number of the Journal, it was stated that the terms Anatomy and Physiology were to be understood in the widest sense as comprehending, not only human and comparative Anatomy and Physiology, but much of Zoology and Palæontology without excluding even Psychology and Pathology.

Professor Humphry of Cambridge took an active part in the preliminary

arrangements for the institution of a journal with this object, and associated with him were Professors Newton of Cambridge, Perceval Wright of Dublin, and the writer of this Preface, then Demonstrator of Anatomy in the University of Edinburgh, with Mr J. W. Clark of Cambridge as editor. The Journal was to appear half-yearly in Royal 8vo, with appropriate illustrations, and Messrs Macmillan & Company were the publishers.

As little encouragement was given to the sale of the first volume, and as the expense of producing the parts in large 8vo was much greater than was anticipated, a new arrangement required to be made. The second volume appeared, therefore, in ordinary 8vo, with Professors Humphry and Turner as the joint conductors, the former of whom undertook for some years the duty of acting editor. With the appearance of volume x. in 1875 an important change occurred. As the circulation of the Journal had improved, it was felt that a more frequent issue than two parts in the year was called for. It was decided to publish in quarterly numbers, and to give more space to physiological papers than had been possible in the preceding volumes. To attain this object, Professors Michael Foster of Cambridge and Rutherford of Edinburgh were conjoined with Professors Humphry and Turner as editors. This association continued for two years, when, from a strong desire on the part of many physiologists to establish a journal specially devoted to their science, Professors Foster and Rutherford resigned their positions on the staff, and Professor M'Kendrick of Glasgow took their place as the physiological editor. On the completion of volume xx. in 1887, a new series was commenced, with Professor Turner as the acting editor.

Owing to the death of Sir George Humphry in 1896, Professors Turner and M'Kendrick invited Professor Macalister of Cambridge, Professor Cunningham, then of Trinity College, Dublin, and Professor Thane of University College, London, to act along with them in the conduct of the Journal, and the two first-named undertook the management.

Shortly afterwards Professor Huntington, of the Columbian University, New York, was added to the editorial staff.

A great impulse was given to the study of human anatomy in our schools of medicine by the foundation, in May 1887, of the Anatomical Society of Great Britain and Ireland. Professor Humphry was chosen as the first President, and through an arrangement made with the Society

this Journal was selected as the medium of publication of its Proceedings. The Society has liberally contributed funds for the preparation of an index (published in 1894) to volumes i.–xx. of the Journal, and subsequently of an index (published in 1897) to volumes xxi.–xxx. It has also from time to time defrayed the charges incurred in producing the illustrations.

The Journal having successfully surmounted the difficulties of its early career, now that it has reached its fortieth volume, may be regarded as having justified the expectation of the founders and conductors that it would become a recognised medium for the publication of original work in the departments of science that it embraces. The present editors regard this as a favourable opportunity for effecting an improvement in its size and fitness for the duty which it discharges. They have arranged, therefore, that in future it should appear with a much larger page, which will enable them to reproduce in a more advantageous form drawings and figures required for its illustration. As the only representative of the founders, who has acted on the editorial staff since the commencement, I have been asked to write a Preface to the new series.

WM. TURNER.

October 1905.

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ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND

AUGUST 1905

THE Summer Meeting of the Society was incorporated with the First International Federative Congress of Anatomy, held in Geneva from 6th to 10th August 1905. Nineteen members of the Society attended the Congress. The President of this Society (Professor J. SYMINGTON, F.R.S.) presided over the Congress on Monday, 7th August. Professor T. H. BRYCE acted as Vice-President on behalf of this Society.

The following resolutions were passed at the Meeting of Congress on Monday, 7th August:—

1. That an International Congress of Anatomy be held at intervals of not less than five years.
2. That one Delegate from each of the Federated Societies form a Permanent Committee.
3. That each Society shall nominate a Substitute who shall serve on the permanent Committee if the Delegate be unable to do so.
4. That the five Delegates shall be able to elect from their number, or from other persons, a Secretary, or, if necessary, two Secretaries, who shall be members of the Permanent Committee.

A Special Meeting of the Anatomical Society of Great Britain and Ireland was held in the School of Medicine, Geneva, on 7th August 1905, at 5 p.m. Nineteen members were present. The President, Professor J. SYMINGTON, F.R.S. occupied the chair.

The following resolutions were passed:—

1. That the President of the Society for the time being be the Delegate on the Permanent Committee of the Congress.
2. That the Secretary of the Society for England for the time being be the substitute for the Delegate on the Permanent Committee of the Congress.

Special votes of thanks were passed to the Canton, Town and University of

Geneva for the hospitality afforded to the Society, to Professor Éternod and the Members of the Swiss Committee of organisation and reception for the successful arrangements which they had made for the accommodation and entertainment of the members of the Society, and to Professor Karl v. Bardeleben, Professor Nicolas and the members of the Secretarial Committee of the Congress, for their arduous and successful labours in arranging the business of the meeting.

The following communications were made to the Congress by Members of the Society:—

(1) Professor J. SYMINGTON, F.R.S., on (*A*) The Development of the Phalanges of the Cetacean Flipper,[1] (*B*) The Relations of the Deeper Parts of the Brain to the Surface.

In communication B the author exhibited a large number of photographs and drawings in illustration of the subject. In April 1903 he published a paper under the above title in the *Journal of Anatomy and Physiology*, and this second commmunication represented an extension of his earlier work with various modifications in the method of investigation. In the first paper the cadaver examined was a female, and the method adopted was to make a series of horizontal sections of the frozen head and from these sections to indicate by orthogonal projections on to the side of the head the vertical and antero-posterior extent of certain of the deeper parts of the brain, the depth of these parts from the surface being shown on the photographs of the various sections. This plan gave excellent results, but it was a very laborious one, a matter of importance when a considerable number of heads had to be examined. Equally satisfactory results were obtained without freezing by thoroughly hardening the entire head in formol and making the sections with a fine saw and a large thin-bladed knife. The head was first divided in the mesial plane, each lateral half placed with its cut surface downwards, and a life-size photograph of the lateral aspect of the head taken by means of a vertical camera provided with a long focus lens. This was done with the integument in position and then with the bone exposed by the removal of the skin and other structures superficial to the cranial wall. When a life-size photo was taken of the median aspect of the opposite half of the head, the position of the various parts of the brain lying in the mesial plane could easily be indicated on a photograph of the lateral aspect of the head. Each half of the brain was then removed and placed with its cut surface on a horizontal slab in its natural position in relation to the median surface of the skull, an outline of which was drawn on the slab. After the outer surface of the brain was photographed various dissections could be made, such as exposing the island of Reil, or opening the lateral ventricles, the brain being restored to its original position before being again photographed. The photographs exhibited included those of the heads of two newly born children and an adult male, and from these diagrams had been constructed indicating the position of the visual and motor tracts in relation to the norma lateralis of the head.

(2) Professor D. J. CUNNINGHAM, F.R.S., *Further observations on the varying form of the Stomach, with special reference to Hourglass Stomach.*

(3) Professor T. H. BRYCE, *The Development of the Thymus Gland in Lepidosiren paradoxa.*[1]

[1] See the current issue (January) of the *Journal of Anatomy and Physiology*, 1906.

(4) Dr JOHN CAMERON, *The Histogenesis of Nerve Fibres.*

An account of this work will appear in a subsequent number of *The Journal of Anatomy and Physiology.* The following is a brief abstract:—

From observations which the author has made on the developing optic nerve in Amphibia, and also on the spinal nerves in embryos of fishes, amphibians, and birds, it would appear that these structures arise both *centrally* and *peripherally.* With regard to the optic nerve in Amphibia, the author has been enabled to ascertain that the axons are actually produced as protrusions from the nuclei of the retinal ganglionic layer which consist of the nuclear matrix, and are, on that account, quite achromatic in the *nascent* condition. Very soon, however, they become "*chromatised*," and thus tend to stain more readily with colouring agents. These axons grow towards the brain along the line of the optic stalk, and the nuclei in the latter position also appear to secrete their achromatic matrix, which aids the growth of the axon, and also in its turn becomes chromatised. The optic nerve in Amphibia thus takes origin centrally from the ganglionic layer of the retina, and also peripherally from the optic stalk, while the material which forms the axon is in both cases primarily nuclear in origin.

As regards the spinal nerves, the author finds that the motor root is formed from the neuroblast-nuclei in the anterior cornu of the spinal cord, but at the same time the *anlage* of the nerve is also laid down concurrently in mesoblast tissue outside the cord. This is evidenced by a proliferation of the mesoblast nuclei along the nerve *anlage,* and at the same time they become separated by a clear achromatic substance which the author identifies as the nuclear matrix secreted from these. This becomes chromatised to form axons in a manner similar to that described in the case of the optic nerve.

A great deal of the difficulty with regard to the histogenesis of nerve fibres has been due to the non-recognition of the nature of the substance in which fibrillation occurs. It may be again stated that this is in all cases nuclear in origin. This present research thus shows that the *anlage* of spinal nerves is laid down in the form of a continuous tract of nuclear achromatic matrix in which the axons are formed by a process of chromatisation. In other words, nerve fibres arise by a combination of the *central* and *peripheral* modes of origin. These observations thus tend to reconcile these two opposite views towards each other, and the author hoped that they would remove a great deal of the controversy which at present exists regarding the origin of nerve fibres in the vertebrata.

Dr Cameron also showed micro-photographs illustrating the development of the retina and of striped muscle.

(5) Dr WILLIAM WRIGHT gave a description of *the Skulls from the Round Barrows of East Yorkshire.* This paper has already appeared in the *Journal of Anatomy and Physiology,* vol. xxxix. p. 417, 1905.

(6) Professor C. J. PATTEN described *The Anthropological Collections* in the Museum of Anatomy, Sheffield University. This paper will be published in the official Records of the Congress.

(7) Dr E. B. JAMIESON gave a *Demonstration of Various Tracts of Fibres and Masses of Grey Matter of the Brain,* displayed by ordinary dissection.

The beautiful preparations shown by Dr JAMIESON comprised the following:—

1. A dissection of the cerebral hemisphere from the inner surface, showing the

intersection of the fibres of the corpus callosum with those of the corona radiata, and the distribution of the fibres of the splenium.

2. A dissection from the inner surface showing the deep aspect of the tapetum and the occipito-frontal fasciculus.

3. A dissection from the inner surface showing the deep aspect of the crusta, the internal capsule and the corona radiata in continuity.

4. A dissection showing the fillet in the medulla, pons, and mid-brain from the ventral aspect.

5. A dissection showing the posterior longitudinal bundle and the fillet in the medulla, pons, and mid-brain from the dorsal aspect.

6. A dissection from the ventral aspect showing the decussation of the superior cerebellar peduncles and the relations of the three cerebellar peduncles to one another.

7. A dissection of pons and medulla showing the trunk, the spinal and mesencephalic roots of the fifth cranial nerve, and the emerging root of the seventh cranial nerve.

8. A dissection showing the seventh nerve more fully exposed and the lateral fillet.

9. A dissection showing the deep aspect of the corpus dentatum of the cerebellum, the roots of the eighth cranial nerve embracing the restiform body, the spinal part of the vestibular root, and the spinal root of the fifth nerve.

10. An isolated corpus dentatum of the cerebellum.

11. Three specimens of isolated lenticular nucleus, one with the anterior white commissure in place, one with the commissure removed, and the third separated along the plane of the external medullary lamina into the putamen and globus pallidus.

12. A dissection of the lower part of medulla and upper part of spinal cord, showing the decussation of the pyramids and the crossed and direct tracts traced for some distance down the cord.

At the same time a number of stereoscopic photographs of several other dissections of the brain was exhibited.

1. The long association tracts from the outer side.

2. The long association tracts from above.

3. The lenticular nucleus and corona radiata from the outer side.

4. The corona radiata, the internal capsule, the crusta, the pyramidal fibres in the pons, the pyramid of the medulla in continuity.

5. Another of the same, with the fillet and lateral fillet, and the inferior cerebellar peduncle spreading out on the cerebellum, also shown.

6. From the basal aspect, various parts of the rhinencephalon as defined by Professor Elliot Smith.

7. The floor of the descending and posterior horns of the lateral ventricle on one side and the roof of the same on the other, both from the inferior aspect.

8. The whole course of the cingulum and of the fornix and the bundle of Vicq d'Azyr, from the mesial and inferior aspects.

9. The corpus striatum and its relation to the internal capsule and corona radiata, from above.

10. The basal ganglia and the optic thalamus dissected from the surrounding brain substance and the internal capsule removed.

11. A dissection of the cerebellum from above, showing the corpus dentatum.

(8) Dr R. J. A. Berry and Dr L. A. H. Jack read a paper on *The Vermiform Appendix of Man and the Structural Changes therein coincident with Age*, and

showed a number of preparations. The paper will appear in full in the April number of the *Journal of Anatomy and Physiology*.

The following conclusions were drawn from the work :—

1. Lymphoid tissue is the characteristic feature of the true caecal apex throughout the animal kingdom, including man. As the vertebral scale is ascended, this tissue tends to be collected together into a specially differentiated portion of the intestinal canal—the vermiform appendix.

2. The amount of lymphoid tissue present at the caecal apex varies, most probably, though not certainly, in accordance with the varying diet of the animal.

3. The vermiform appendix of man is not, therefore, either a vestigial remnant or an organ in a state of retrogression, but is an actively functional lymph gland.

4. The appendix of man is not equally functional throughout the whole of life. At birth it contains practically no lymphoid tissue, within six weeks it has become a lymph gland and continues as such during the first half of life, after which it progressively declines in functional activity. Lymphoid tissue is, therefore, a tissue of the growing animal.

5. Obliteration of the vermiform appendix is a pathological process.

6. The functions of the human appendix are the same as those of any other collection of lymphoid tissue in any other part of the body.

(9) Dr JAMES MILLER gave an account of his *Researches in the Elastic Tissue of the Lung*, which are published in this number of the *Journal*.

(10) Professor J. T. WILSON read a note on *the Fate of Tænia Clino-orbitalis* (Gaupp) *in Echidna and Ornithorhynchus*[1] respectively, and demonstrated specimens.

Professor WILSON also made the following demonstrations :—

1. *Demonstration of stereo-photographs of wax-plate models of the skull of a young mammary fœtus of Ornithorhynchus.*

The work of plastic reconstruction was carried out under Professor Wilson's direction in the Anatomical Laboratory of the University of Sydney, by Mr W. T. Quaife, student of medicine.

The first and smaller model ("A") represents that segment of the otic region of the chondrocranium which is associated with the tympanic apparatus, and includes the proximal portions of the cartilaginous visceral skeleton which constitute the latter.

The second and larger model ("B") represents the entire osteo-cartilaginous skeleton of the head, with the following exceptions :—The skeleton of the snout and nasal region previously modelled and described by the author (*Proc. Linn. Soc.*, N.S.W., for 1901, part iv.); the symphysial region of the mandible with the distal portion of Meckel's cartilage; the hyoid apparatus beyond its proximal segment; the occipital, and the posterior planes of the Otic, regions of the skull, and the membrane bones of the vault of the cranium.

The developmental anatomy of the Orbito-sphenoidal region, and of the tympanic and maxillo-mandibular apparatus, formed the main objects of the investigation.

Pending a more detailed account of the results of the work, the following points may be noted as evident :—

There is a general agreement in structure with that of the skull of the corresponding stage in Echidna, of which a wax-plate reconstruction was also shown at the Congress by Professor Gaupp.

[1] See the current issue (January) of the *Journal of Anatomy and Physiology*, 1906.

The character and relations of the "Ala temporalis" closely resemble those described by Gaupp in Echidna, but its cartilaginous extremity is traversed by a short horizontal canal, transmitting the "Vidian" artery, which, in Ornithorhynchus, is a larger arterial branch of the carotid than that which enters the cranium through the small "foramen caroticum."

There is a slight prominence or spur upon the Tænia clino-orbitalis, not far from the posterior attachment of that structure.

The malleus is still wholly continuous with Meckel's cartilage, and the cartilaginous incus appears as a mere flange-like appendage of the malleus, lying incurved on its medial aspect. At their junction the cartilaginous continuity of the two elements is uninterrupted.

The stapes is an independent cartilaginous nodule, conoidal in shape.

The hyoid arch is completely continuous with the periotic capsule, and the Chorda tympani turns forwards, laterally to its base, to enter the tympanic cavity. The proximal extremity of the malleus-incus mass is also in part continuous with the periotic cartilage.

The processus folianus mallei is an independent bony splint which is perforated by the Chorda tympani as this proceeds towards its junction with the "lingual" branch of the Trigeminus.

Two pterygoid elements are present, of which one (the pterygoid of the adult) lies caudal of the massive palatine, whilst the other is implanted in, and supported by, a groove in the dorsal aspect of the palatine. This subsequently fuses with a pterygoid downgrowth of the basisphenoid.[1]

The zygomatic process of the maxilla extends backwards so far as to enter into relation with the squamo-mandibular articulation.

A small but quite definite malar or jugal element is present as a constituent element of the zygomatic arch.

The head of the mandible is rounded and massive and its interior is cartilaginous.

2. Exhibition of photo-micrographs illustrative of the *anatomical and histological characters of a "Nucleus postremus," or "Nucleus areæ postremæ,"* i.e. *a definite and distinct neuronic group present in the human medulla oblongata in the position of the "Area postrema" of Retzius.*

Professor J. T. Wilson and Dr J. P. Hill, Sydney, N.S.W., Australia, also showed lantern-diapositives and photo-micrographs illustrative of *various stages in the development of Monotremes and Marsupials.*

NOVEMBER 1905

The Annual General Meeting of the Society was held at St Bartholomew's Hospital, London, E.C., on Friday, 24th November 1905, at 4 p.m. There were twenty-four members and eight visitors present. Professor Symington, F.R.S., was in the chair.

[1] Gaupp has recently shown reason for believing that the second of the two pterygoids above referred to is the genuine mammalian "pterygoid" element; and that it is homologous, not with the reptilian pterygoid, but with the posterior paired element of the submammalian parasphenoid.

Mr SIDNEY SCOTT showed a number of photographs of *sections of the thorax*.

The minutes of the previous meeting were read and confirmed.

The President was directed to sign the agreement, a copy of which had been circulated to the members, proposed between the Editors of the *Journal of Anatomy and Physiology* and the Members of the Anatomical Society.

The members, as recommended by the Committee of Management, for the Council for the year 1906 were unanimously elected.

The Treasurer's Report was received and adopted.

The following candidates were unanimously elected members of the Society:— Miss Hamilton, M.B., Demonstrator of Anatomy, The London School of Medicine for Women; E. P. McLoughlin, M.D., Professor of Anatomy, The Catholic School of Medicine, Dublin; E. B. Jamieson, M.B., C.M., Demonstrator of Anatomy, The University of Edinburgh; O. Charnock Bradley, M.B., C.M., Professor of Anatomy, Royal Veterinary College, Edinburgh; James Miller, M.D., Demonstrator of Pathology, The University, Birmingham; Edward Phelps Allis, M.D., Palais Carnalés, Menton.

Discussion and Papers:—

(1) Mr J. W. THOMSON WALKER introduced a discussion on *the surgical anatomy of the prostate*, and showed preparations.[1] The following is an abstract of his communication:—

The sheath of the prostate is formed by the rectovesical fascia, and envelops the organ, except at its basal attachment to the bladder and at the apex, where it becomes incorporated with the striped muscle surrounding the urethra. The sheath may be stripped off the prostate in the lateral and posterior surfaces, but not along the anterior surface, where it is firmly adherent to the organ. The anterior portion of the sheath differs from the rest of the envelope. It is firmly adherent to the prostate, and is not formed by the layer of fascia which passes down over the lateral aspects of the gland. In the surface of this part of the sheath is a thin layer of fascia, which corresponds to the upward reflexion of fascia over the bladder. Beneath this is a thick band, the fibres of which are irregularly set and imbedded in them are masses of fat and non-striped muscle and the veins of the prostatic plexus.

The prostate is adherent to the under surface of the bladder base, and extends backwards for about $\frac{1}{2}$ inch behind the urethra to about the middle of the trigone. The greatest lateral extent is in a line passing outwards and backwards from the urethra, and measures about $\frac{9}{16}$ of an inch on each side. The trigone of the bladder is a definite muscular triangle which is formed by a bar of muscle passing between the ureters and a band from each ureter to the urethra. These bands unite, and pass on into the wall of the urethra.

Beneath these longitudinal fibres is a flat layer of circular fibres, which may be distinguished from the rest of the circular bladder muscle. This layer becomes thicker as it approaches the urethra, and forms a wedge behind the urethral opening,

[1] This paper will appear in full in a subsequent issue of the *Journal of Anatomy and Physiology*.

and then passes on into the urethral wall. This circular muscle is not found in the bladder wall in front of the urethra, but forms a thick layer along the anterior wall of the prostatic urethra. The non-striped sphincter is formed by these layers of circular muscle. The outer longitudinal layer of bladder muscle is inserted into the base of the prostate.

The ready stripping of the sheath of the prostate is an important point in the operations of perineal and suprapubic prostatectomy. For the suprapubic operation certain changes are necessary in the bladder base.

The sphincter is dilated by the protrusion of a nodule of prostate into the bladder, and the finger can thus be pushed through the lumen of the sphincter, and need not penetrate through the muscle of the bladder floor.

The striped muscle in relation to the prostate forms a ring surrounding the urethra at the apex of the gland. Thence it passes up beneath the anterior layer of the sheath as far as the bladder wall. This striped muscle probably plays an important rôle in retaining the urine after suprapubic prostatectomy.

The prostatic plexus passes up the front of the prostate, and at the junction of this organ with the bladder gives off two branches which surround the bladder neck at its junction with the prostate. The shape of the whole plexus is roughly that of the letter **Y**.

The principal veins of the plexus lie imbedded in the thick band of fascia which forms the anterior layer of the sheath, and do not come into direct relation with the capsule of the gland.

The prostatic urethra is vertical and straight at its supramontanal part, but below the verumontanum it curves forward. The prostatic urethra is removed with the prostate in the majority of cases of suprapubic prostatectomy without causing any change in the sensory part of the reflex act of micturition.

The gland tissue of the prostate is in the form of a horseshoe at the base of the gland, with the urethra in the same plane as the anterior borders of the lateral lobes. No separate middle lobe could be found. The capsule of the organ was the unappropriated margin of the non-striped muscle stroma.

The seminal vesicles were placed horizontally along the upper borders of the prostatic lobes.

Mr Cuthbert Wallis agreed with many of the views expressed by Mr Thomson Walker. He was, however, strongly of opinion that the tumours of the prostate were adenomata; that in the operation of prostatectomy they were shelled out, and that a surrounding shell of prostatic tissue was left behind.

Mr P. L. Daniel agreed with the view expressed by Mr Cuthbert Wallis, and pointed out that the small amount of hæmorrhage attending the operation was evidence that the prostatic plexus was not injured, which would be unavoidable if the whole gland were taken away. He discussed the pathology of the prostatic tumours in question, and held that they were simply overgrown and distended prostatic glands—a urethral infection starting the process in the first place.

Dr Keith and the President also joined in the discussion, to which Mr Thomson Walker replied.

(2) Professor J. T. Wilson read a paper on *the anatomy of the calamus region in the human bulb*, and gave an account of a hitherto unrecorded "*nucleus postremus*." [1]

[1] This paper will appear in full in a subsequent issue of the *Journal of Anatomy and Physiology*.

(3) Professor J. Symington, F.R.S., showed specimens illustrating *the topographical anatomy of the caput gyri hippocampi.* In this communication it was shown that the longitudinal furrow on the caput gyri hippocampi, named sulcus rhinencephalus inferior by Professor G. Retzius, is simply an impression on the cerebral cortex caused by the anterior part of the free edge of the tentorium cerebelli, and not a true sulcus. The paper was illustrated by specimens and photographs.

(4) Mr F. G. Parsons read notes on *the coronal suture,*[1] and showed by many specimens from different mammalian orders that the forward projection of the anterior inferior angle of the parietal bone was correlated to the retracting action of the temporal muscle on the lower jaw.

(5) Professor A. M. Paterson, on behalf of himself and Dr Emerys Roberts, demonstrated the conditions of *the vertebral column, ribs, sternum, and thoracic cavity in an example of ectopia of the heart and viscera,* and discussed the bearing of these conditions on the question of the development and morphology of the sternum.

[Details of the conditions will be given later in the account of the whole series of the peculiarities presented by the specimen.]

[1] This paper will appear in full in a subsequent issue of the *Journal of Anatomy and Physiology.*

PROCEEDINGS OF THE

ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND

JANUARY 1906

A MEETING of the Society was held at University College, London, on Friday, 19th January, 1906. There were eighteen members and twenty visitors present. The President, Professor J. SYMINGTON, F.R.S., occupied the chair. The minutes of the previous meeting were read and confirmed.

The following were elected members of the Society:—PHILIP TURNER, M.S., 8 St Thomas's Street, London, S.E.; HENRY MULREA JOHNSTON, M.B., Demonstrator of Anatomy, Trinity College, Dublin; and EDWARD D. DAVIS, Demonstrator of Anatomy, Charing Cross Hospital, London, W.C.

1. Professor THANE exhibited:—

(1) A sacrum showing a costo-transverse foramen on the left side of the first vertebra (fig. 1).

(2) A specimen in which the upper pulmonary vein of the left side opens into the innominate vein (fig. 2).

The accompanying drawings of these two specimens have been kindly made by Mr T. W. P. Lawrence.

2. Mr T. W. P. LAWRENCE showed preparations (1) of the parts from a case of progressive muscular atrophy, (2) of an abnormal lung, and (3) of a double vagina and uterus.

3. *Mr SYDNEY SCOTT read a paper giving records of the *Decussations of the Brachial Plexus.*

4. Dr C. E. BEEVOR showed a *Right Cerebral Hemisphere exhibiting complete interruption of the fissure of Rolando* by a gyrus which passes

* Papers marked thus * appear in full in the *Journal of Anatomy and Physiology.*

FIG. 1.

FIG. 2.—I.M.V., internal mammary veins; P.V., pulmonary veins; Ao., aorta; P.A., pulmonary artery; Br., bronchus.

above the inferior genu from the ascending parietal convolution into the superior frontal gyrus. This bridging gyrus is separated from the middle frontal gyrus by the continuation of the inferior part of the fissure of Rolando into the sulcus præcentralis superior. It was taken from a man aged twenty-five, who died from peritonitis after appendicitis, and who did not present any cerebral symptoms during life. The condition is very rare. Dr Beevor had injected between eighty and ninety brains, and this was the only example.

In Professor Cunningham's work on the Surface Anatomy of the Primate Cerebrum it is stated that, according to Heschl, this condition was found six times in 2174 (or once in 362) hemispheres, and, according to Eberstaller, twice in 200 brains.

In the figure from Sernoff's case, given in the above work, the lower part of the fissure of Rolando is not continuous with the sulcus præcentralis superior, as in this case.

5. *Dr F. J. MACKENZIE showed a specimen in which *the hind-gut opened into a cloacal chamber* in a child aged one year and eleven months.

6. *Professor PATERSON described, for Dr EMRYS-ROBERTS, the main features of a case of *partial thoracic and complete abdominal ectopia viscerum*, in which there were also present other abnormalities, including retroflexion of the vertebral column, hydrocephalus and spina bifida, defective formation of the large intestine, arrest of development of the cloaca, and absence of the allantois.

7. *Professor E. FAWCETT read a paper, illustrated by specimens and thirty-seven microphotographs, on *the Ossification of the Upper Jaw.*

A second paper, illustrated by specimens and microphotographs, was read by Professor FAWCETT on *the Ossification of the Palate Bone.* He showed that

(*a*) The palate bone is ossified in membrane by a *single* centre at the side of the nasal part of the fœtal oral cavity, and that the ossification extends to the base of the skull.

(*b*) Ossification takes place at the time the embryo is about 19 mm. in length in the vertical plate of the bone on the inner side of the palatine nerves.

(*c*) The horizontal plate is not formed until the embryo reaches some 24 mm. in length and the two halves of the palate have become horizontal.

(*d*) The orbital and sphenoidal processes are not ossified as independent centres, as stated by Lambaud and Renault, but are outgrowths from the vertical plate comparatively late.

(*e*) The sphenoidal process is throughout fœtal life larger than the orbital one.

(*f*) Up to the second or third year the antero-posterior length of the palate bone is greater than the height.

(*g*) The groove for articulation with the internal pterygoid plate is enormously larger than the other grooves on the tuberosity.

(*h*) The palate bone is third in sequence of ossification, succeeding the superior maxilla.

MARCH 1906

A MEETING of the Society was held at Guy's Hospital, London, S.E., on Friday, 9th March, 1906, at 4 p.m. There were eighteen members and ten visitors present. Dr KEITH (Vice-President) occupied the chair.

The minutes of the previous meeting were read and confirmed.

The following were elected members of the Society:—D. C. L. FITZWILLIAM, M.B., C.M. Ed., 17 Queen Street, Mayfair, W.; FRANCIS S. MACKENZIE, M.B., C.M. Ed., The County Hospital, York; and Miss H. M. PIXELL, B.Sc., Bedford College, London, W.C.

1. Mr PHILIP TURNER exhibited:—

(1) A specimen showing *the two common carotid arteries arising from a common trunk*, and

(2) A specimen in which *the right subclavian artery arose from the dorsal aorta.*

2. Dr ARTHUR KEITH showed:—

(1) Three specimens in which *the œsophagus ended blindly opposite the tracheal bifurcation*, and in which the distal portion of the œsophagus was prolonged from the lower end of the trachea.*

(2) A specimen in which the pericardium was widely open on the left side.* The condition really was one of great distension of the iter venosum (Lockwood) owing to the intrapericardial growth of the lung.

(3) Specimens in which *the auriculo-ventricular bundle of His* was displayed. (It was arranged that Dr Keith should introduce a discussion on the structure of the heart at the meeting at Belfast in June.)

3. *Professor FAWCETT showed a number of specimens illustrating ossification:—

(1) Specimens of *the hip-bone* from 55 mm. fœtuses, mounted in balsam as microscope slides, were shown to indicate that, almost contemporaneously with the appearance of an entochondral centre in the ilium, there appears behind this a fan-shaped ectochondral centre which extends right through the mesoblastic hip-bone and is not superficial to the cartilage as in ordinary ectochondral ossification. It was stated that, as usually described, a centre first appeared in the cartilage of the hip-bone above the great sacro-sciatic notch, that this was followed by ectochondral ossification in the neighbourhood of the posterior inferior iliac spine, and perhaps in that part of the bone which bore the posterior limb of the auricular facet. This was followed by the ordinary ectochondral ossification along the margin of the great

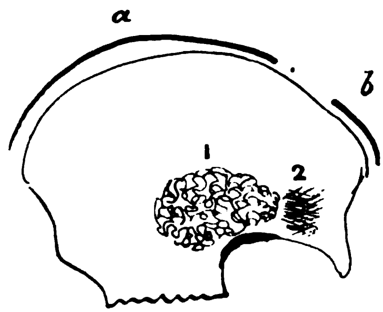

FIG. 3.—1. Entochondral bone; 2. ectochondral bone; *a.* anterior crest segment; *b.* posterior crest segment.

sciatic notch at its deepest part. The point of interest is that cartilage-formed bone does not extend to the posterior inferior spine. Specimens of more advanced age showed the iliac crest to be completed by two epiphysial masses, one for the dorsal third the other for the ventral two-thirds. This was well marked in the skeleton of a boy of eighteen years of age (see fig. 3).

(2) *The sacrum.*—Here it was pointed out that the sacrum showed at eighteen years of age those epiphyses which complete the costal processes as in the lumbar region. That these costal epiphyses appeared in the intervals between the free extremities of all the costal processes, two between S_1 and S_2, two between S_2 and S_3, and that these lay at the front and back of the intercostal fissure. By their expansion, partly in the downward, chiefly in the upward direction, they formed the auricular epiphysis, an epiphysis which resembled that of the centium of a vertebra in being mainly a marginal one. The costal epiphyses of S_3 and S_4

were single, that for S_4 being of large size, and therefore ossifying earlier than the others.

These costal epiphyses of S_3 and S_4 might unite with one another directly, forming a very narrow marginal epiphysis to the so-called tuberosity. The costal epiphysis of the third sacral vertebra was very small; that of the fourth, as before said, being very large. It soon makes union with the epiphysis of the transverse process of S_5, and the common mass so formed gives rise to the tuberosity after having received the down-going epiphysis of the transverse process of S_4. The tuberosity then was a mass compounded of costal epiphyses of S_3 and S_4, and epiphyses of transverse processes of S_4 and S_5.

The epiphyses for the transverse processes exist in the first, third, fourth, and fifth. That for the first is large, and may grow down to form a part of the auricular surface, especially along the anterior margin. Those for the fourth and fifth are large and comma-shaped, and, as has been before said, join with one another and with the costal epiphyses of S_3 and S_4 to form the tuberosity.

In one specimen of sacrum there were epiphyses for the mammillary processes of the first sacral vertebra, and epiphyses for the spurious processes.

One specimen showed a sacrum fusing on one side with the fifth lumbar vertebra; and this specimen was really the key to the series, as here the costal epiphysis of the fifth lumbar vertebra was shown forming a wedge between that process and the corresponding one on the first sacral vertebra.

(3) *The fifth lumbar vertebra.*—This was a specimen of eighteen years of age, and it showed that the so-called costal process is not only costal but transverse as well, and that each element has its own epiphysis, a condition accentuated in the first sacral vertebra.

(4) A lantern slide of a coronal section of the head of a human embryo of 70 mm. length. It showed that there appears at the junction of the eminentia articularis with the remainder of the squamous part of the temporal bone, a mass of cartilage: both squamous and zygomatic seem to plunge into this. The backward extent of this cartilage coincides with that of the condyle of the jaw.

(5) A lantern slide of a coronal section of the same embryo showing that the cartilaginous part of the great wing of the sphenoid does not extend beyond the pterygoid crest, and that the alisphenoid, pterygoid crest, and external pterygoid plate are not preformed in cartilage.

(6) *Two patellæ* showing ossification just commencing by two centres lying side by side.

3. Dr H. M. JOHNSTON showed specimens of *Supernumerary Carpal Bones.*

4. *Dr WALTER KIDD showed a number of *micro-photographs of the skin of the foot and hand* in various mammals.

5. *Dr EVELYN J. EVATT read a paper on the *Development and Evolution of the Papillary Ridges on the Volar Surfaces of the Hand.*

6. *Mr S. MAYNARD SMITH and Dr G. J. JENKINS read a paper on the *Watersheds of the Peritoneum,* in which they showed the directions taken by fluid free in the abdomen in different positions of the body.

7. Mr E. S. FRAZER read a paper on the *Morphology of the Hypothenar Muscles,* in which he controverted Brooks's view of the origin of some of the short muscles of the little finger.

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JOURNAL OF ANATOMY AND PHYSIOLOGY

ON THE DEVELOPMENT OF THE HIND-BRAIN OF THE PIG.

By O. CHARNOCK BRADLEY, M.B., D.Sc., F.R.S.E., *Royal Veterinary College, Edinburgh.* (PLATES I.–XI.)

PART I.

PROBABLY because the description given by the late Professor Wilhelm His of the development of the human hind-brain was so clear and detailed, only a comparatively small number of investigators, during the past twenty years, have turned their attention to this province of mammalian embryology. Nevertheless, in the somewhat sparse literature which does exist, several questions of importance have been raised, and conflicting opinions expressed. To mention only one point of surpassing interest and importance, all are not agreed as to the formation, degree of development, and histogenetic function of the rhombic lip (Rautenlippe) in embryos of mammals other than Man. There are those who are not satisfied as to its formation even in the human embryo.

In the conviction that the examination of even an isolated species of mammal may afford additions to the sum of facts from which valuable generalisations may be deduced, it was decided to investigate some of the steps of the development of the hind-brain of the pig.

In most cases two embryos, of equal size, were chosen from the same litter; the one being sectioned in a sagittal, the other in a coronal direction. In the case of the younger material more than two embryos were examined.

With the exception of two embryos where such a proceeding was not deemed necessary, models were made, according to Born's wax-plate method, of the hind-brain of all the different stages herein described. In many instances it was considered advisable to make two models from the same embryo—one of the whole of the hind-brain, and another of part of

that organ under greater magnification. By this means, it is hoped, greater accuracy of description has been attained.

The following table shows the material employed in this research:—

	Age of Embryo.	Length of Embryo.	Models.
1.	19 days.	...	(1) × 50. (2) × 100.
2.	22 ,,	8 mm.	(1) × $41\frac{2}{3}$. (2) (part) × $83\frac{1}{3}$.
3.	25 ,,	15 ,,	(1) × $41\frac{2}{3}$. (2) (part) × $83\frac{1}{3}$.
4.	$28\frac{1}{4}$,,	23 ,,	(1) × $27\frac{7}{10}$. (2) (part) × $83\frac{1}{3}$.
5.	30 ,,	25 ,,	(1) × 18. (2) (part) × $35\frac{5}{7}$.
6.	35 ,,	32 ,,	(1) × 18. (2) (part) × $35\frac{5}{7}$.
7.	...	37 ,,	...
8.	...	43 ,,	...
9.	40 ,,	52 ,,	× $35\frac{5}{7}$.
10.	48 ,,	80 ,,	× $26\frac{6}{7}$.
11.	55 ,,	100 ,,	× $35\frac{5}{7}$.
12.	70 ,,	150 ,,	(part) × $71\frac{3}{7}$.

Although the "age" of the different embryos is given above, it is not intended that this should signify more than the length of time which elapsed between the time of coition and the time when the mother was destroyed. An examination of Keibel's *Normentafel* (1) shows that coition and fertilisation of the ovum are not by any means contemporaneous, or even approximately so in the pig. In embryos taken from two litters, it not infrequently happens that those which should be farther advanced in development, judging from the period which has elapsed since sexual congress took place, are as backward as, or even more backward than, those of the "younger" litter.

General Description.

19-*days' Embryo.*—In the embryo taken from the uterus 19 days after coition, the hind-brain is still in a rudimentary condition. The fissura rhombo-mesencephalica (Kupffer) is distinct, and the cervical flexure is well marked; but the pontine flexure has only begun to be formed (fig. 1). The hind-brain, as a whole, is in the form of a slightly bent tube, the calibre of which is greatest at about the junction of the anterior third with the posterior two-thirds. The roof of the tube is membranous from the

cervical flexure to within a short distance from the constriction which marks the anterior limit of the hind-brain. The cerebellum is very rudimentary, and, indeed, is very difficult of accurate definition. Immediately behind the fissura rhombo-mesencephalica there is a short non-membranous dorsal union between the two halves of the neural tube; but, with this exception, the primitive Anlagen from which the future cerebellum arises are only connected by the membrana obturatoria quarti ventriculi (Kölliker). (Fig. 9.)

Transverse sections taken anywhere, except at the most anterior part of the hind-brain, present a remarkable similarity, whether they are from the medulla or the region of the cerebellum. It is noteworthy that, though the alar and basal laminæ are clear and distinct in the spinal cord and in the mid-brain, it cannot be said that they are precisely defined in any part of the hind-brain. In fact, the hind-brain at this stage consists of two lateral plates (fig. 9), diverging from each other more and more as the widest part of the neural tube is approached; but joined ventrally at an acute angle, indicated on the surface of the model by a median ventral ridge, which, though more pronounced in the region of the future pontine flexure, can readily be traced all the way from the cervical to the cephalic flexure.

From the above it will be seen that there is practically a uniformity of construction of the whole of the hind-brain at this period of development.

In this embryo there are seven neuromeres lying between the cephalic and cervical flexures (fig. 2). Attention has been called to these structures elsewhere (2). It is, therefore, unnecessary to give more than a brief account of them here. The interior of the neural tube presents seven grooves, of unequal extent and depth, corresponding to elevations on the exterior. Following the lead of previous observers, these grooves, with the external elevations produced by them, are held to indicate the presence of neuromeres. Longitudinal sections show that the height of the ridges separating the neuromeral grooves is often disproportionate to the depth of the constrictions between the external elevations.

The first neuromere is large and from it the cerebellum arises, as has been shown by Orr (3), Hill (4), and Kupffer (5). The seventh neuromere is second in point of size, and has a deep and extensive internal depression. Whether it is a neuromere of the hind-brain or of the spinal cord may be open to question, since Hill, after careful examination of the neuromeres of fishes and the chick, has announced it as his conviction that there are never more than six neuromeres in the rhombencephalon.

22-*days' Embryo.*—In the hind-brain of an embryo 22 days old, the cervical flexure is more abrupt and the pontine flexure better marked than in the 19-days' embryo (fig. 3). The two lateral parts of the cerebellum have increased in size, and their median connection is more extensive. As

a consequence of these developments, the outline of the membranous roof of the ventricle (Rautenfeld) has changed. Those lateral borders of it which lie in front of the greatest transverse width of the rhombencephalon are now convex towards the middle line, instead of concave as previously. This, and the subsequent changes in the outline of the "Rautenfeld," are similar to those figured by Grönberg as occurring in Erinaceus (6).

The distinction between alar and basal laminæ can now be traced from the spinal cord into the medulla, but only for a short distance. The median ventral ridge, spoken of in connection with the younger embryo, is now confined to the district occupied by the pontine flexure and the isthmus rhombencephali, but in this situation it is even better marked than previously.

Seven neuromeres can still be detected (fig. 4). Their internal depressions are deep and very clear, but the corresponding external elevations and the intervening constrictions have become faint. The seventh depression is more shallow than before, and the sulcus between the alar and basal laminæ (sulcus limitans) is continued into it.

An examination of the two youngest embryos herein described reveals in a very clear manner the nerve-connections of the neuromeres. Stated briefly, these are as follows:—The N. trigeminus arises primarily from the second neuromere, but establishes a secondary connection with the third also. The acustico-facialis root-complex is associated with the fourth neuromere, and the glosso-pharyngeus and vagus with the sixth and seventh respectively. The nerve-relationship, as here stated, is almost in entire accord with the description given by Prenant (7) of the condition found by him in a 14-mm. pig embryo.

In the 22-days' embryo the otic vesicle lies opposite the fifth and the greater part of the sixth neuromere. In the 19-days' embryo it does not extend so far backwards, and it is therefore concluded that the real relationship of the vesicle is with the fifth neuromere, the association with the sixth being merely the result of expansion of the vesicle.

A more detailed description of the neuromeres is given in the paper already published.

Grönberg (6), in his description of the development of the brain of the hedgehog, attaches great importance to the appearance of two longitudinal grooves, lateral to the sulcus centralis, in the anterior part of the floor of the ventricle in the earlier stages of development. The more lateral of the two he considers to be the true sulcus limitans; the more mesial he holds to be only a secondary structure, and names it the sulcus intermedius. This latter, however, he avers is equivalent to what His has recognised as the sulcus limitans of the human embryo. Thus Grönberg desires to shift the sulcus between the alar and basal laminæ into a more lateral position.

A comparison of fig. 11 (transverse section through the hind-brain of a 22-days' pig embryo) with Grönberg's fig. 59 (Taf. 18) reveals a strong likeness. Grönberg's figure is from a hedgehog embryo of about the same stage of development as the 22-days' pig; and the section is from about the same level as that from which fig. 11 was taken. Both figures show two *apparently* longitudinal grooves; but the model of the pig embryo discloses the neuromeral nature of the grooves. Is there not the possibility that the grooves in Grönberg's illustration, and called by him sulcus limitans and sulcus intermedius, may bear a like interpretation? This is merely a query, not an assertion. Nothing short of making reconstruction-models of the hind-brain of hedgehog embryos would justify one in saying that Grönberg's reading is not the correct one. At the same time, it is strange that the two figures should be so much alike.

15-*mm. Embryo.*—In an embryo 15 mm. long (25 days old) the pontine flexure is well marked (fig. 5). This, in association with the increased size of the cerebellar lamina, has produced a great alteration in the shape of the outline of the Rautenfeld. It is now in the form of a triangle whose base, directed forwards, consists of a median notch flanked on each side by a convexity produced by the lateral portions of the posterior border of the cerebellum. Its posterior angle no longer quite reaches the cervical flexure; and, since the lateral recesses are beginning to form, its lateral angles are curved slightly forwards.

In addition to the increased antero-posterior dimensions of the lateral parts of the cerebellum, there has also been an augmentation of their thickness. The inner surface of each half is now convex; but this is not entirely due to an increase in thickness, for there has been the concomitant production of an external concavity. The median part of the cerebellum has begun to develop a marked convexity in the sagittal, and also in the transverse direction—a condition of some moment, as subsequent development will show.

Immediately behind the posterior edge of the cerebellar lamina a choroidal fold has begun to form. This begins laterally in the neighbourhood of the incipient lateral recess, and is continued for more than two-thirds of the distance between this point and the middle line. Something less than the median third of the lamina shows no sign of folding.

The ventral median ridge, present in the earlier stages, has entirely disappeared, and has given place to a shallow groove continuous with the ventral groove of the spinal cord. The groove extends forwards to a level with the origin of N. trigeminus. Anterior to the origin of the N. acustico-facialis there is a low rounded ridge running along the floor of the groove.

Alar and basal laminæ can now be followed from the spinal cord for

about half the length of the ventricle, *i.e.* nearly to the most anterior root of the IX. and X. cranial nerves (fig. 12). Of the neuromeral grooves five are still evident (fig. 6). The first, however, is shallow; the second is of good depth, and the ridge between it and the first is very prominent. The five grooves now present have the same nerve relations as had the most anterior five of the seven in the earlier stages. The sixth and seventh neuromeres have, therefore, lost their internal grooves, and it appears that this has resulted from an anterior extension of the interzonal sulcus (sulcus limitans); in support of which supposition may be cited the fact that the sulcus is much wider in the position of the former sixth and seventh neuromeres.

The fact that alar and basal laminæ cannot be distinguished in the early rhombencephalon, and that, as growth proceeds, they gradually extend, as recognisable entities, farther forwards, appears to justify emphasis.

23-*mm. Embryo.*—The pontine flexure is so pronounced in this embryo, that the floor of the ventricle slopes gently downwards and forwards from its posterior end to opposite the lateral recess (fig. 7). Anteriorly it is inclined steeply upwards and forwards.

The lateral recess is now deep and clearly bounded. Its posterior limit has become defined, partly as the result of the increase of the pontine flexure which has caused the ventricle to assume suddenly a much greater transverse diameter in front of the N. acustico-facialis; but partly, also, as the result of intrinsic development of the hind-brain in this region. The cerebellum, because of its increase in size and its greater backward projection produced by the accentuation of the pontine flexure, now completely roofs in the lateral recess.

The increase in the thickness of the floor of the ventricle has caused the distinction between alar and basal laminæ to become a matter of difficulty. But there is still a faint groove visible opposite the fasciculus solitarius.

It will be noticed that, in the pig, definite alar and basal laminæ separated from each other by a sulcus limitans have not been met with in the anterior part of the rhombencephalon. The farthest anterior point at which they can be distinguished is about the middle of the length of the ventricle, and this only in an embryo of 15 mm. In younger material they cease to be obvious at a more posterior level.

Although the indications of neuromeres are generally held to disappear at a comparatively early period, there are grooves in this and older embryos which it is difficult not to consider as the direct descendants of the neuromeral grooves of younger specimens. A comparison of figs. 6 and 7 will demonstrate the grounds for supposing that the grooves persist for a much longer time than is generally supposed. That grooves do exist in a 23-mm. embryo is shown in fig. 7; and these grooves—four in number—have the

same topography as have similar depressions in fig. 6. If the grooves in the older embyro are not the descendants of those in the younger, it is strange that they should be so similar in position and relations. Until the contrary is shown to be the case, the depressions in the 23-mm. and larger embryos will be described as being identical with those of the earlier embryos.

The first and second depressions are partly combined, *i.e.* they are now included in one large concavity; but their individuality is not completely lost, since the grooves which extend laterally from them into the lateral recess of the ventricle are quite distinct from each other. The second depression is much deeper than the first.

At the present period of development the third groove has gained the supremacy so far as depth is concerned. There is yet a fourth depression, shallow and indistinct, and into it runs the possible representative of the sulcus limitans. Microscopic sagittal sections suggest the presence of even a fifth depression, but concerning its actuality there is some room for doubt.

25-*mm. Embryo.*—In an embryo only 2 mm. longer than the one just described (25 mm., 30 days old) the pontine flexure has attained its maximum curvature. From now onwards it gradually becomes more obtuse. The extreme degree of the flexure at this period produces a great exaggeration in the depth of the medium fissure of the ventricle on a level with the lateral recesses. These latter are now very definitely bounded—above by the cerebellum, and below in a manner presently to be described (fig. 23).

The connection between the two halves of the cerebellum has increased in thickness in that part adjacent to the mid-brain. Posteriorly it gradually thins away. The lateral halves of the cerebellum are still concave on the outer surface—this being in striking contrast to a convexity occurring in the median region.

By this time the choroid plexus is well formed, and is disposed in the form of a curve whose concavity looks forwards.

Of the depressions considered in the last embryo as vestiges of the neuromeral grooves, four can still be distinguished. Internal to the opening from the body of the ventricle into the lateral recess, the first and second grooves are more blended than in the 23-mm. embryo; but into the recess itself they can readily be traced as separate entities. Their relative positions, however, have been altered owing to the increase of the pontine flexure. The first groove now lies at a higher level than the second, instead of being directly anterior to it.

The third groove continues to be deep in the body of the ventricle, but it is with difficulty followed into the recess. The fourth groove is faint and indistinct, and can be satisfactorily demonstrated only in sagittal microscopic sections.

32-mm. Embryo.—The rhombencephalon of the next older embryo shows several features of interest. The pontine flexure is less abrupt. The transverse and vertical diameters of the medulla are much greater than those of the spinal cord; the change occurring rather suddenly at the cervical flexure. The fourth ventricle fails to reach the cervical flexure; that is, the intercalated portion of the medulla (*Schaltstück* of His) has begun to form. The dorsal median fissure of the spinal cord is continued into this part of the medulla, but gradually becomes shallower as it passes forwards. A short distance behind the posterior tip of the ventricle the bottom of the fissure develops a ridge, to which attention will be directed later (fig. 24).

Viewed from the surface, the two halves of the cerebellum do not meet at so sharp an angle as formerly. The outer surface of each half has still a slight concavity about its middle (fig. 31), but its posterior portion is decidedly convex (fig. 30). The external convexity of the median region of the cerebellum, which had made its appearance in the previous embryo, is now very prominent, and does not extend so far back as the posterior border of the cerebellum (figs. 30 and 31). Viewed from the inside, the two halves of the cerebellum are separated by a median saggital fissure which is very deep on a level with the external convexity just mentioned. This fissure has taken the place of a wide groove, previously present, corresponding to the thin median connection of the two moieties of the cerebellum. The change from a fairly wide groove into a contracted cleft has doubtless been due to two factors. In the first place, the outward bulging of this part of the cerebellum, without a commensurate increase in vertical thickness, must have contributed to the deepening of the groove. Secondly, the lateral walls of the groove have become steeper and taller because of the increase in thickness of the lateral halves of the cerebellum, and the resulting increase in the internal convexity of these parts.

In the posterior part of the cerebellar lamina, and in the wider part of the fissure just described, a prominent ridge has made its appearance (fig. 30). The ridge, however, disappears as the deeper, more anterior, portion of the fissure is approached. The occurrence of a ridge is no doubt associated with the initiation of the process of filling up of the fissure. It is of interest to note that Schaper (8) figures a similar, if larger, ridge at the bottom of the "Medianfurche" (ventral surface of the "Deckplatte") in trout embryos (*cf.*, for example, his fig. 28). It may be remarked that a similar ridge is present (and was also visible in the 25-mm. embryo) at the bottom of what may for convenience be called the ascending (anterior) portion of the median fissure (sulcus centralis) in the floor of the ventricle Even in the 23-mm. embryo the precursor of the ridge can be detected.

It should be here noted that at no time in its development does the

cerebellum of the pig present the internal features described by Kölliker (9) as occurring in the rabbit. Kölliker remarks that frontal sections reveal, on the under (inner) surface of the developing cerebellum, a deep median and two lateral fissures. The surface, therefore, he says, has four longitudinal ridges running along it; of these the more lateral are the largest. This assertion is supported by the figure of a frontal section (fig. 338) through the cerebellum of a 16-days' rabbit embryo. In its lack of the lateral fissures, the pig resembles the sheep (*cf.* Kuithan's figures).

The general character of the lateral recess has not altered materially, though its roof and floor are nearer together owing to addition to the thickness of the cerebellum by which the roof is formed. Because of a diminution in the transverse diameter of the ventricle just behind the opening into the recess, the isolation of the latter is rendered more conspicuous.

In the body of the ventricle there is a shallow depression, occupying the same relative position as the first and second grooves described in the preceding paragraphs as neuromeral in origin. From this depression a deep furrow runs outwards into the lateral recess, in the outer and anterior part of which it divides into two—thus, possibly, indicating its duplex constitution. The third groove is of great depth in the body of the ventricle, and can be readily followed into the lateral recess.

52-*mm. Embryo.*—In the next embryo (40 days) the intercalated part of the medulla has increased materially in extent. The cerebellum has developed rapidly, and, examined from the exterior, now shows a division into an elementary vermis and two lateral hemispheres. The vermis is most markedly developed anteriorly, where it forms a rounded projection overlying the rudimentary anterior medullary velum, and extending for some distance in front of the anterior limit of the hemispheres. Such an early indication of a vermis seems to militate against Bolk's contention that it is not a fundamental division of the cerebellum (10).

There can be little doubt that the vermis has sprung directly from the median convexity present in the earlier embryos. Thus the median thin portion of the cerebellum only produces a very small part of the vermis, almost the whole of it being developed from the more mesial parts of the lateral halves of the cerebellar lamina.

The transverse diameter of the cerebellum is much greater than that of the underlying portion of the rhombencephalon (figs. 42 and 43). The sulcus, which has been described elsewhere (11) as demarcating the nodulus and flocculus from the rest of the cerebellum, is now present. The deep sagittal median fissure found on the inner surface of the cerebellum in the previous embryo has become a veritable cerebellar ventricle (figs. 43 and 44), such as has already been described in mammalian

embryos by Blake (12). This narrow cavity extends forwards into the anterior projection of the vermis, so that its communication with the rest of the fourth ventricle is directed downwards and backwards. (*Cf.* figs. 43 and 44.) In the depth of the cerebellar ventricle there is still a trace of the median ridge already mentioned (fig. 43).

The under surface of the anterior medullary velum is marked by a sagittal furrow, which may be looked upon as a shallow forward continuation of the fissure out of which the cerebellar ventricle has developed.

It is, perhaps, worthy of remark that a ridge has made its appearance where the cerebellum joins the floor of the fourth ventricle (fig. 42).

In the posterior part of the floor of the fourth ventricle the lateral halves of the medulla are inclined to each other at a very acute angle, a condition which has been evolved gradually since the earlier stages. A ridge can still be distinguished at the bottom of the median fissure in the anterior part of the ventricle (figs. 42 and 43), but this is the oldest embryo in which such a feature is found.

The depression occupying the position of the first and second neuromeral grooves is becoming very indistinct. The third groove, on the other hand, is deep and very evident in the body of the ventricle, and is continued into the lateral recess as a conspicuous furrow.

The opening from the ventricle into the lateral recess has become both relatively and absolutely narrower.

80-*mm. Embryo.*—The cerebellum in an 80-mm. embryo (48 days) has an unmistakable vermis and two lateral hemispheres. Fissures are beginning to separate the lobes: the nodulus and flocculus being already completely demarcated from the rest of the cerebellum. The cerebellar ventricle has become filled up to a large extent, but is not as yet completely obliterated. Where the cerebellum meets the floor of the ventricle there are now three short ridge-like elevations in the place of the one in the younger specimen.

The groove occurring on the under surface of the anterior medullary velum is now very shallow.

The floor of the ventricle has altered scarcely at all in the interval between 40 and 48 days. The third neuromeral groove is still represented by a deep depression in the body of the ventricle; but it now lies at a level slightly in front of the opening into the lateral recess, whereas, formerly, it was on a level with the opening. This change of position is to be associated with a backward growth of the anterior wall of the recess, rather than to a forward movement of the depression. The subsequent history of the third neuromeral groove shows that there is little reason to doubt that it becomes the anterior fovea of the floor of the

fourth ventricle. It may be again repeated that, if the depression is not really a persisting neuromeral groove, there is nothing in the series of embryos examined which militates against the contention that it is so.

100-*mm. Embryo*.—The third neuromeral depression is again deep and occupies a position considerably anterior to the opening into the lateral recess, into which no continuation of it can now be demonstrated.

The three ridge-like eminences at the junction of the cerebellum with the floor of the fourth ventricle are more prominent than in the earlier stage. The anterior medullary velum is thin, its ventricular surface showing a median sagittal keel corresponding to a dorsal furrow. Even now the cerebellar ventricle has not entirely disappeared.

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EXPLANATION OF FIGURES.[1]

The outlines of all the figures representing sections were made by means of a Leitz camera lucida.

The figures illustrating sections are arranged so that the first figure belonging to one particular embryo represents the most posterior section; the last figure of the series representing the most anterior.

The following reference lettering is common to all the figures:—

a.c. ala cinerea.
a.l. alar lamina.
a.m.v. anterior medullary velum.
a.p. area postrema.
b. backward projection of the roof of the fourth ventricle.
b.l. basal lamina.
bl.vs. blood vessels.
cb. cerebellum.
c.c. central canal.
c.v. cerebellar ventricle.
ch.pl. choroid plexus.
d.m. dura mater.
floc. flocculus.
f.s. fasciculus solitarius.
f.sp. funiculus separans.
fw. Flügelwulst.
h.b. hind-brain.
l.r. lateral recess.
m.b. mid-brain.
nX. etc. nucleus of X etc. cranial nerve.
ob. obex.
o.v. otic vesicle.
pfl. paraflocculus.
p.m.v. posterior medullary velum.
r.l. rhombic lip.
s-a.s. subarachnoid space.
1, 2, 3, *etc.* 1st, 2nd, 3rd, etc., neuromeral grooves.
V. etc. V. etc. cranial nerves.

Fig. 1. 19 days' embryo. Model of the hind-brain. Exterior.
Fig. 2. 19 days' embryo. Model of the hind-brain. Interior.
Fig. 3. 22 days' embryo. Model of the hind-brain. Exterior.
Fig. 4. 22 days' embryo. Model of the hind-brain. Interior.
Fig. 5. 15 mm. embryo. Model of the hind-brain. Exterior.

Fig. 6. 15 mm. embryo. Model of the hind-brain. Interior. More than half of the brain has been modelled. The cut surface, therefore, is greater than it would be in the middle line.

Fig. 7. 23 mm. embryo. Model of the region of the lateral recess. Interior.

Fig. 8. 150 mm. embryo. Model showing half of the most posterior part of the fourth ventricle and the central canal. From within and in front.

Fig. 9. 19 days' embryo. Horizontal section through the hind- and mid-brain.

Figs. 10 and 11 22 days' embryo. Transverse sections through the hind-brain.

Figs. 12–15. 15 mm. embryo. Transverse sections through the hind-brain.

Figs. 16–20. 23 mm. embryo. Transverse sections through the hind-brain. Fig. 19 shows the amount of development of the rhombic lip of the cerebellum in the region of the lateral recess.

Figs. 21–23. 25 mm. embryo. Transverse sections through the hind-brain.

Figs. 24–31. 32 mm. embryo. Transverse sections through the hind-brain.

Figs. 32–44. 52 mm. embryo. Transverse sections through the hind-brain. Figs. 34–40 illustrate the form and dimensions of the rhombic lip at different levels.

[1] The cost of reproduction of the figures has been defrayed by the Carnegie Trust for the Universities of Scotland.

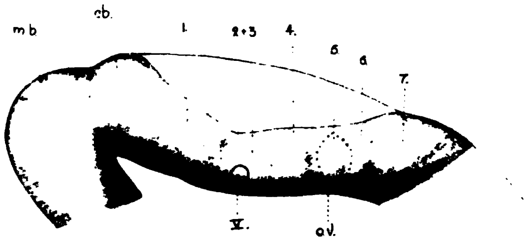
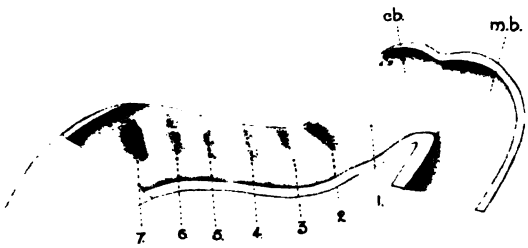


FIG. 1.



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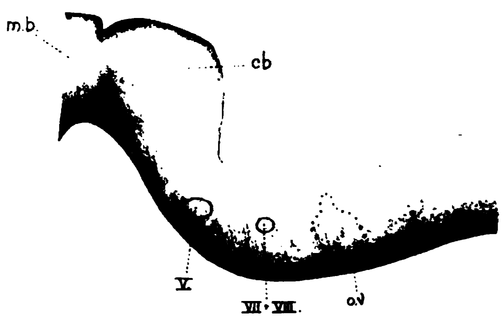

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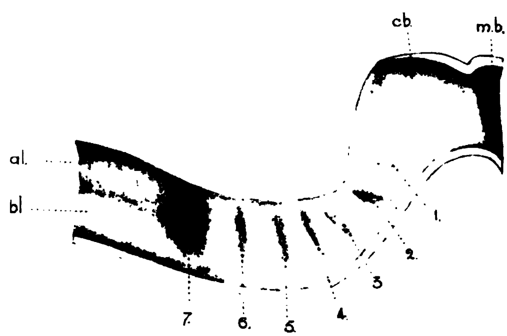

FIG. 4.

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FIG. 5.

FIG. 6.

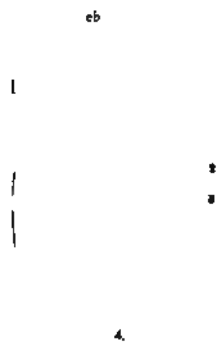

FIG. 7.

FIG. 8.

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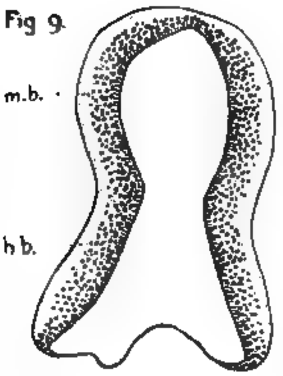
Fig 9.



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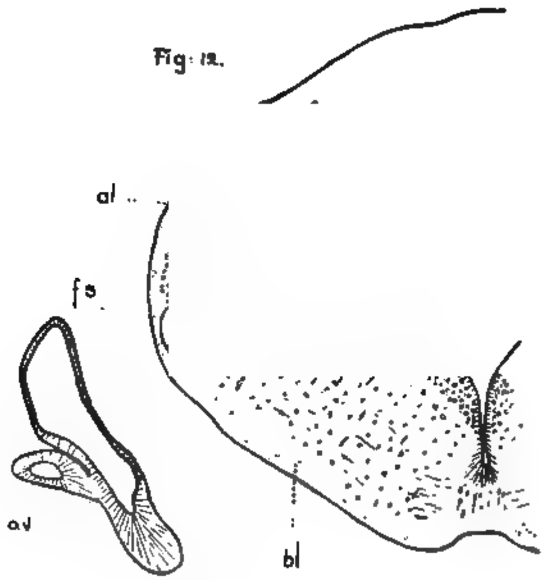

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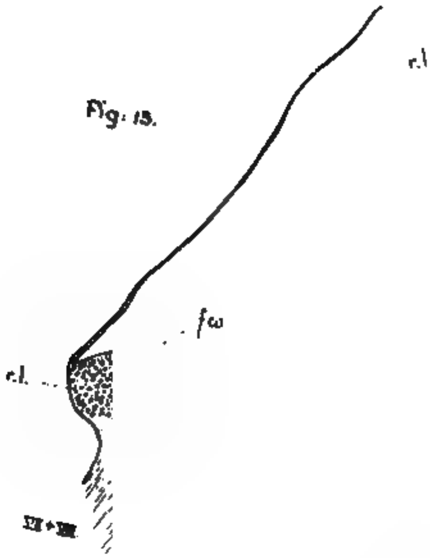
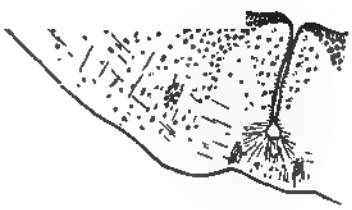
Fig. 14.

Fig. 15.





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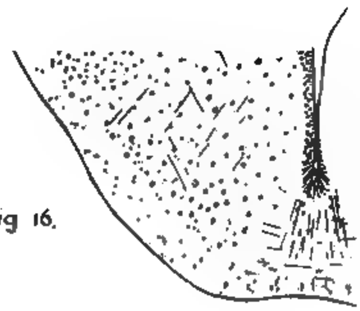

Fig 16.

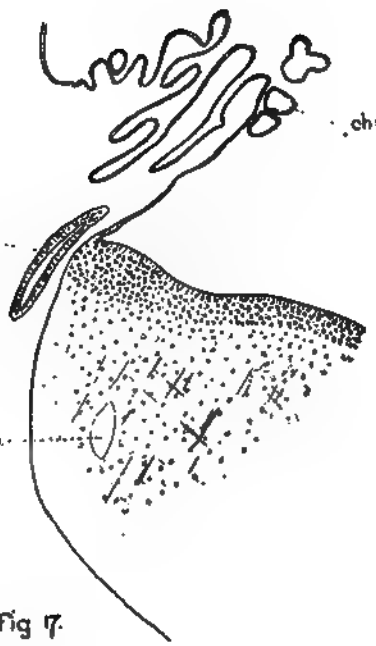

Fig 17.

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Fig. 18.

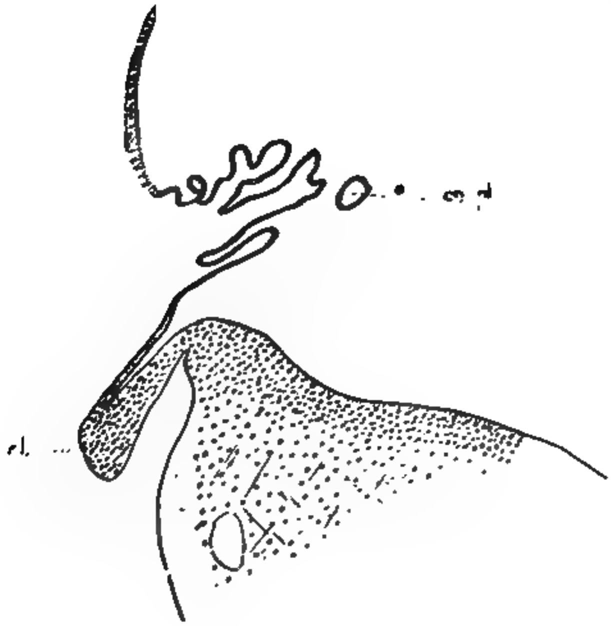

Fig. 19.

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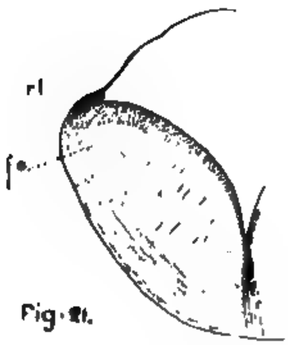

Fig. 21.

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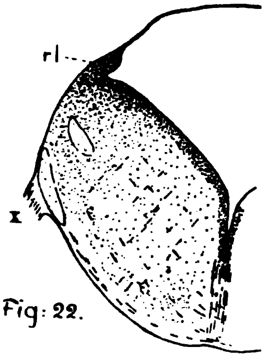

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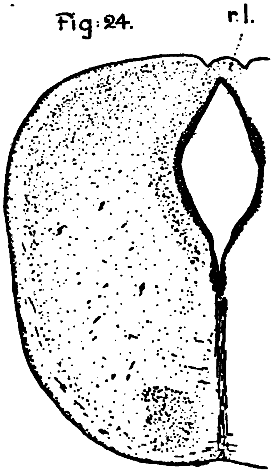

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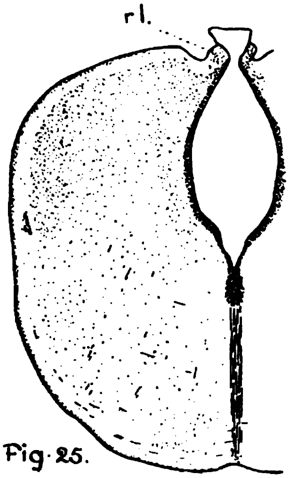

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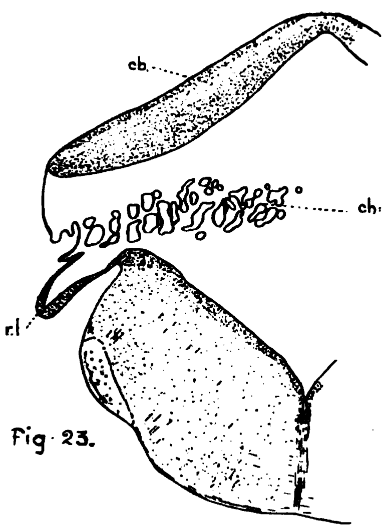

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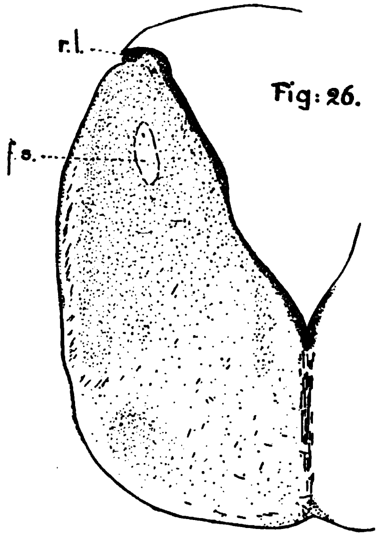

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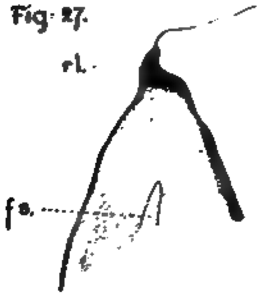
Fig. 27.



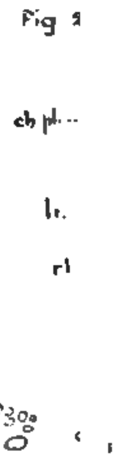
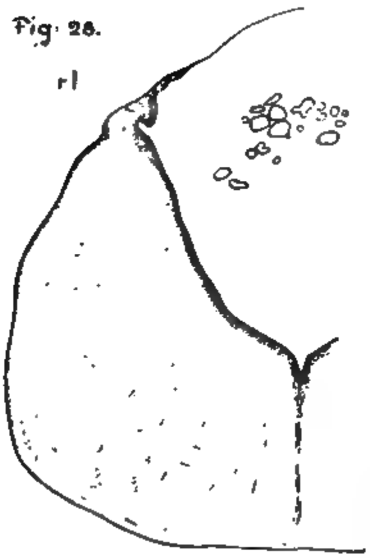


Fig. 28.



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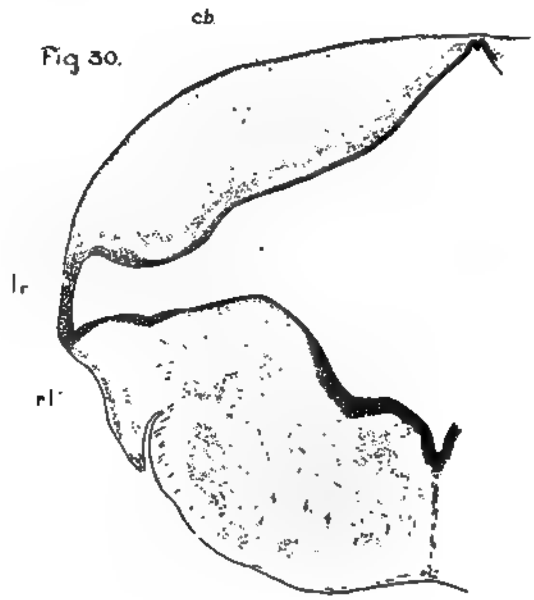

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Fig: 32.

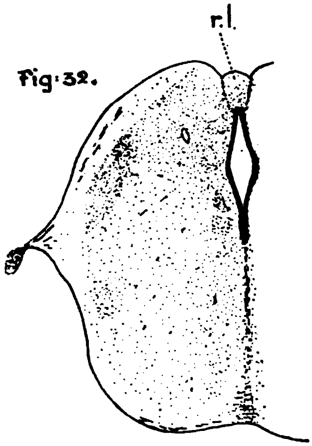

Fig 34.

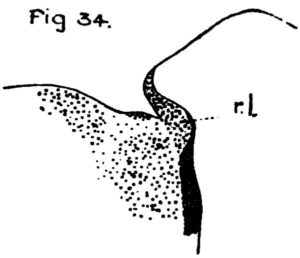

Fig: 33.

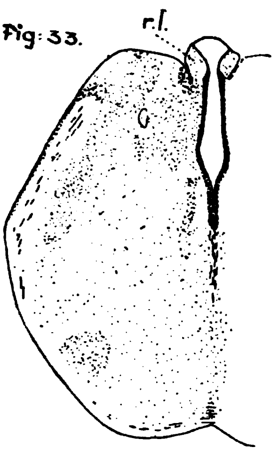

Fig: 35.

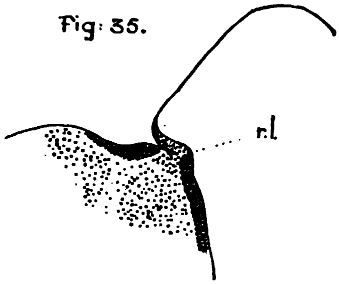

Fig: 36.

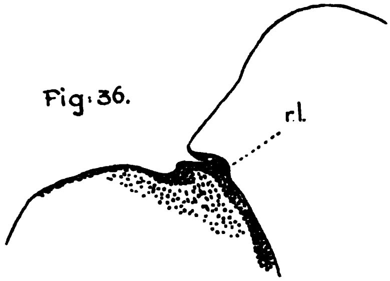

Fig: 31.

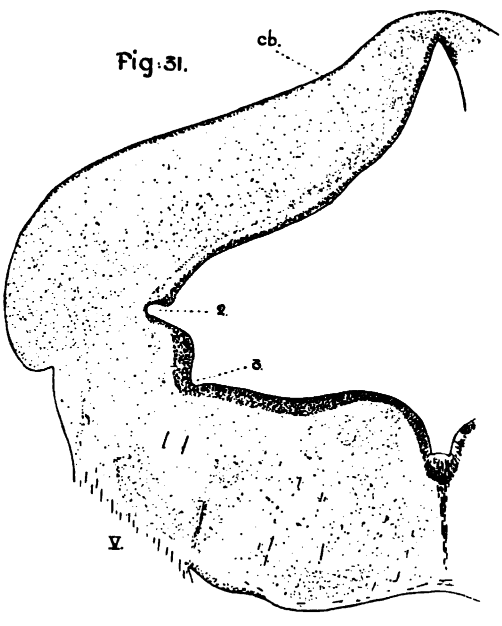

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Fig: 37.

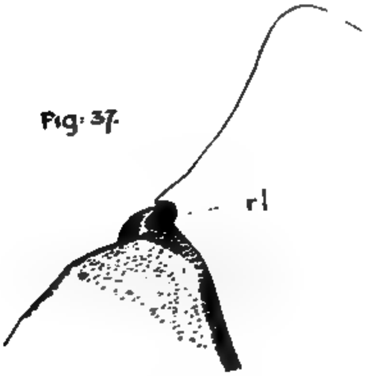


Fig 38.

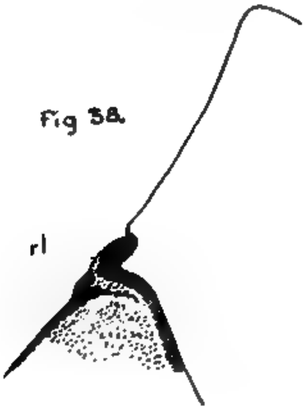


Fig 39.

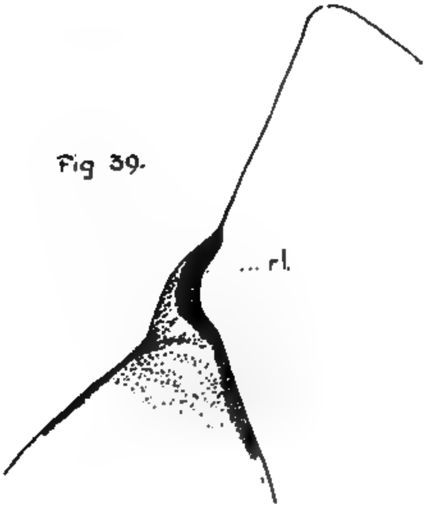


Fig 41.

PROFESSOR O. CHARNOCK BRADLEY.

Fig. 42.

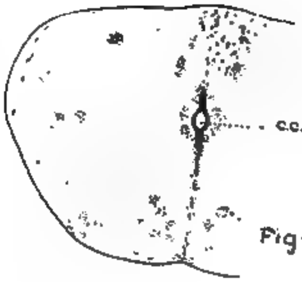


Fig. 45.

Fig. 43 cb.

c.d.

Fig. 46.

Fig. 44. cb.

NOTE ON THE ELASTIC TISSUE IN THE EYE OF BIRDS. By E. WACE CARLIER, M.D., F.R.S.E., etc., *Professor of Physiology in the University of Birmingham.* (PLATES XII., XIII.)

PART I.

Methods.—The eyes were bisected into anterior and posterior halves, and after removal of lens and vitreous humour the anterior halves were placed in picro-corrosive formaline mixture (Mann's method).[1] When thoroughly fixed, they were taken up the alcohol series into absolute alcohol, for which benzole was gradually substituted; they were then transferred to a mixture of paraffin and benzole, and finally placed in pure paraffin of high melting point and cast into blocks.

Radial sections, including all the coats of the eyeball, were then made through the corneo-sclerotic junction, smoothed on warm water and arranged on albumin-coated slides. After removal of the paraffin the sections were stained with Weigert's elastic stain, differentiated in 90 per cent. alcohol, and finally mounted in xylol balsam. Other sections were stained by well-known histological methods for purposes of comparison.

DOMESTIC FOWL—*Gallus*. (Fig. 1.)

The membrane of Descemet (posterior elastic lamina) is elastic throughout, though it stains by no means vividly with Weigert's stain. Either from this membrane, or from the fibrous tissue of the cornea immediately in front of it, intensely stained elastic fibres arise to pass backwards on the inner edge of the sclerotic to open out and form a network which comes into relation with a great number of elastic fibres that have a circular course around the eyeball. These circular fibres make their appearance anteriorly on a level with the junction of the cornea to the conjunctiva; at first a few fibres only are visible near the outer edge of the sclerotic, arranged one behind the other in rows, but they soon, however, become more numerous and spread towards its inner aspect, becoming very numerous where the white fibres of the sclerotic tend to encircle the eyeball. Mingled with these to some extent are numerous fine fibres that encircle the canal of Schlemm.

[1] G. Mann, *Physiological Histology*, Oxford, 1902, p. 97.

These three sets of fibres fill this region with a fine elastic network.

The outer half of the sclerotic contains no elastic fibres except where the conjunctival connective tissue joins with that of the sclerotic. Here, however, elastic fibres are numerous; they belong to the conjunctiva and not to the sclerotic, and form a dense sub-epithelial elastic bundle with an oblique trend, that starts from the junction of the conjunctiva with the cornea.

At the level of the bony plates elastic fibres make their appearance in the outer part of the sclerotic; they are chiefly confined to the periosteum, and take for the most part a circular course round the eyeball. The perichondrium of the cartilage cup that envelops the eyeball posteriorly also contains some elastic fibres; at first numerous, they quickly disappear from the outer surface, but on the inner aspect of the cartilage plate they are more numerous, arcuate in arrangement, and extend quite round the eye.

Between the bony plates and the ciliary muscle the inner half of the sclerotic contains very many elastic fibres that have a circular course; they diminish greatly in number as the cartilage is reached, and finally they disappear almost entirely.

The ciliary muscle arises from white fibrous tissue in front of the canal of Schlemm, in which many arcuate elastic fibres, continuous with those surrounding the canal, may be seen, and in addition a few very fine elastic fibres run in the endomysium between the muscle fibres throughout its length; they lie on the fibres, have a somewhat wavy course, and increase in number towards its insertion into what are practically bundles of coarse elastic fibres that spring at the level of the ora serrata (fig. 6), partly from the choroid and partly from the perichondrium of the inner surface of the cartilage cup. About midway in their course these two bundles of elastic fibres intermingle for a while, to again separate into a number of short insertion slips for each fibre of the muscle. Nearly all these fibres have an antero-posterior course so that the muscle when it shortens draws on the choroid with an elastic and not with a rigid pull, thereby insuring against shock and consequent injury which a sudden contraction of the powerful striped fibres with which the bird's eye is furnished might produce; at the same time the part of the tendon inserted into the cartilage, which contains rather more fibres than the part inserted into the choroid, is put on the stretch, and as the cartilage cannot be drawn forwards, this band will act as a spring to produce a very rapid elongation of the muscle when its contraction ceases and so produce a rapid return to a condition of complete negative accommodation.

Many circular elastic fibres are commingled with the arcuate fibres of

this tendon, especially on the inner side of its choroidal half; they can be traced forwards in the choroid until they become continuous with those of the ciliary processes.

Crossing the angle between the iris and the cornea are numerous strands of fibres that constitute the pectinate ligaments; they consist of bundles of coarse elastic fibres covered by endothelium, which arise from the elastic network of the sclerotic from the point of splitting of Descemet's membrane nearly to the level of the anterior edge of the cartilage cup. These bundles are thickest anteriorly and pass well forwards to the iris, after entering which they suddenly disappear and fail to reach the body of that structure. Behind these the bundles are thinner or consist of single coarse elastic fibres only, that form an open-meshed elastic net, the fibres of which sweep across the ground plate of the ciliary processes in a thick maze of fibres to end close under the uveal cells which cover the processes, by becoming continuous with the arcuate fibres that lie just outside the pigment of the pars ciliaris, which in their turn unite with the fibres of the choroidal insertion of the ciliary muscle.

The body of the iris contains no elastic fibres except those in the blood-vessel walls, and none can be detected within the corneal tissue.

PIGEON—*Columba livia* (domestic var.).

In this bird, the only part of Descemet's membrane stained by Weigert's method is a narrow band along its corneal surface, which, when traced backwards, splits into very fine fibres that become quickly lost among the elastic fibres of the sclerotic, and cannot in any way be said to give rise to them. The elastic fibres of the sclerotic arise in the fibrous tissue of the corneo-sclerotic junction, somewhat anterior to the junction of the conjunctiva with the cornea; they begin as a few isolated circular fibres near the middle of the structure, which soon become numerous and extend backwards in a wedge-shaped arrangement to become intermingled with arcuate fibres; then more and more circular fibres make their appearance between this wedge and Descemet's membrane until the inner half of the sclerotic becomes filled with a fine network of elastic fibres, in the meshes of which lie the white fibres from which the ciliary muscle takes its origin—the few fibres contributed to this network by Descemet's membrane being quite insignificant.

The outer half of the sclerotic contains very few elastic fibres, except opposite the origin of the ciliary muscle, where a dense and ever-widening network, mostly of circular fibres, is continuous anteriorly with the network of the inner half and extends backwards to the anterior edge of the

cartilage cup, to the perichondrium of which it furnishes fibres as well as to the periosteum of the bony plates.

The conjunctiva contains many elastic fibres, mostly sub-epithelial in position.

The fibres of the ciliary muscle are accompanied by a few elastic fibres that lie along them, and are inserted into a mass of elastic threads which, after an arcuate interwoven course, split into two bundles, of which the one, ending in the choroid at the level of the ora, is somewhat thicker than the other, which ends in the perichondrium of the cartilage cup at about the same level. A few elastic fibres run in the choroid beyond the ora towards the back of the eyeball.

The pectinate ligaments consist of several coarse elastic fibres united together and clothed with endothelium; they spring from the sclerotic—not from Descemet's membrane—and cross the angle towards the ciliary processes to end under the uveal cells. From this a bundle of arcuate fibres runs backwards, external to the pars ciliaris, to become continuous with the choroidal elastic insertion of the ciliary muscle. A few of the finer anterior pectinate fibres end abruptly in the iris, only penetrating it for a very short distance.

There are no elastic fibres in the body of the iris except in the coats of the vessels, and none in the cornea.

The Lapwing—*Vanellus cristatus*.

The whole thickness of Descemet's membrane is feebly stained, its corneal margin being the most deeply coloured part. Posteriorly it breaks up into a network of elastic fibres that go to form the pectinate ligaments, which cross the angle in the usual manner to end chiefly in the ciliary processes just external to the uvea, the remainder reaching the iris along which they extend for a short distance, finally ending abruptly without penetrating into its body. Like Descemet's membrane, from which they spring, they stain but faintly with Weigert's dye.

From the ciliary processes some elastic fibres extend backwards along the insertion of the pars ciliaris retinæ; they are few in number, obscured by the pigment cells of the part, and end some distance from the insertion of the ciliary muscle into the choroid.

The ground plate of the ciliary processes is narrow in this bird, but contains numerous elastic fibres. From the corneal tissue behind Descemet's membrane the elastic fibres form a fringing network lying on the inner surface of the sclerotic, only penetrating its structure for a slight distance so that a considerable area of tissue between the network and the canal of

Schlemm is free from elastic fibres of any size, though a few small ones, just visible with a magnification of 1000 diameters, may be detected in it.

Outside Schlemm's canal the sclerotic is absolutely free from elastic elements.

The ciliary muscle, which is of large size, must therefore take its origin from white fibres; but its insertion is into a dense though thin strand of elastic fibres that fills the whole space between the cartilage cup and the choroid coat, into which it is eventually fixed by a long insertion reaching to the level of the ora, a few fibres only going to the sclerotic.

THE DOTTEREL—*Charadrius morinellus.*

This bird feeds by picking up small larvæ, crustacea, etc. from among the stones on the sea-shore. Descemet's membrane is elastic throughout; it thickens posteriorly to split into a network containing elastic fibres that passes backwards in the sclerotic and divides to enclose the canal of Schlemm, on the inner side of which most of the elastic fibres lie; they are coarse and circular in arrangement with very few arcuate fibres amongst them.

The fibres of the pectinate ligaments are long, thin, and made up of several elastic threads; they do not crowd the angle to any extent—the most anterior strands run well forwards to the iris, where they suddenly end just under the endothelium, leaving the body of the iris free from elastic tissue. The ground plate of the ciliary processes is full of elastic fibres that extend quite to the tips of the processes in long strands, which soon fade away posteriorly into a network of fine threads that have for the most part a circular course; and this again becomes continuous with the thick band of elastic fibres into which the ciliary muscle is inserted. This band extends backwards to the level of the ora, nearly all its fibres terminating in the choroid; a few fibres, however, run to the cartilage cup to end in its perichondrium.

In the sclerotic behind Schlemm's canal are numerous fine elastic threads having a circular course; they soon disappear, leaving the tissue between the bony plates and the ciliary muscle practically free from elastic tissue. A few fine elastic threads are also present in the endomysium of the ciliary muscle.

MOORHEN—*Gallinula chloropus.*

Descemet's membrane is thin and elastic throughout; it thins off posteriorly into a minute thread that joins the elastic network of fibres in the inner part of the sclerotic coat; the fibres of this network spring from the fibrous tissue just in front of the termination of Descemet's membrane,

and thence spread backwards in a wedge-shaped formation to enclose the canal of Schlemm, at which level many of the fibres are circular in arrangement. On the inner side of the canal these fibres are coarse, elsewhere they are thin and exhibit no very definite arrangement; beyond the canal the tissue internal to the ciliary muscle is full of circularly running fibres that extend nearly to the insertion of the muscle. The outer part of the sclerotic also contains some minute elastic fibres whose course is mostly arcuate, though some run circularly.

The conjunctival elastic tissue is very fine, mostly longitudinal in its trend and scattered throughout its thickness.

From the network on the inner side of the sclerotic many coarse elastic fibres spring, which in crossing the angle often unite to form thicker strands; they pass forwards to the iris, into which they penetrate for some little distance, to become united with fine elastic fibres in the walls of the numerous blood-vessels that lie on the anterior aspect of the iris in this bird; others, and they are the most numerous, run into the ciliary ground plate, where they unite with an antero-posteriorly running network of coarse fibres that completely fill the ground plate; few fibres, if any, enter the ciliary processes. Anteriorly, this network stops at the iris; posteriorly, it extends as numerous arcuate fibres along the choroid to unite with the insertion bundle of the ciliary muscle. The angle is by no means crowded with elastic fibres, and the spaces of Fontana are therefore wide.

The ciliary muscle arises from white fibrous tissue, in which a few elastic fibres are visible; it passes backwards to be inserted into its elastic tendon, which splits as usual into two strands—an external smaller bundle that runs to end in the perichondrium of the cartilage cup, and an inner larger bundle that runs along the outer surface of the vascular layer of the choroid to end about the level of the ora serrata.

THE MAGPIE—*Pica rustica.* (Fig. 2.)

Descemet's membrane, which is elastic throughout, thins off suddenly into a fine network on the surface of the fibrous tissue. From the junction of the cornea with the sclerotic across its whole breadth, fine elastic fibres spring to converge inwards and backwards until they pass internal to the canal of Schlemm, near which the arcuate fibres are more conspicuous than elsewhere, either from being coarser or from being gathered into bundles. On the outer side of the canal the sclerotic also contains many fine elastic fibres having a circular course; they are scattered, and envelop the anterior margin of the bony plates, on the outer surface of which they become

continuous with the very numerous elastic fibres of the loose tissue outside the eyeball and with those of the conjunctiva.

The pectinate ligaments are very numerous, of medium thickness, closely packed together, and entirely composed of elastic tissue coated with endothelium. They spring from the inner border of the sclerotic and almost completely fill the angle between it and the iris, after crossing which they extend forwards within the iris for some distance to become continuous with the elastic fibres which are present in considerable number along its posterior surface and base. Most of the pectinate ligaments end in the ground plate of the ciliary processes, from which fibres pass forwards to the iris and inwards to the ciliary processes, where, however, they are not very numerous, and finer than in most birds. From the ground plate the fibres may be traced backwards among the pigment cells of the choroid to the insertion of the ciliary muscle into the usual bundle of coarse elastic fibres, which, when traced backwards, is seen to split into two strands—the one to terminate in the sheath of the sclerotic cartilage, where it suddenly fades away; the other, somewhat shorter, ends as suddenly by becoming merged with the elastic network around the choroidal vessels.

From the point of origin of the ciliary muscle many elastic fibres spring which accompany the muscle fibres, and may become merged with the network in the inner part of the sclerotic, which chiefly consists of fine circular fibres that are numerous within the bony plates, and may be traced, though in diminishing numbers, to the level of the outer lip of the cartilage cup, where they practically disappear.

There is, therefore, much elastic tissue present in the eye of this ground-feeding bird.

THE ROOK—*Trypanocorax frugilegus.*

The membrane of Descemet is not stained by Weigert's method, and therefore probably does not consist of elastin; in this it resembles the same structure in most mammals.

The elastic fibres, which are confined to the inner half of the sclerotic, take origin at the level of the junction of the conjunctiva with it; they are very fine, few in number, and circular in arrangement. The fibres of the pectinate ligaments arise from a very shallow elastic network on the inner aspect of the sclerotic, which receives no elastic tissue from Descemet's membrane. This network appears to be continuous with that starting from the junction; but, owing to the number of pigment cells present, this could not be ascertained with certainty. The pectinate ligaments consist of thin bundles of elastic fibres that pass over to the iris and ground plate of

the ciliary processes, along the border of which they practically end, only a few minute fibres passing into the ciliary processes.

The ciliary muscle arises from a tissue that contains few elastic fibres, and is not accompanied by any in its course. It is inserted, however, into the usual thick strand of arcuate fibres that splits posteriorly into two bundles—one passing to the perichondrium of the cartilage cup, and the other ending in the choroid coat. Most of its fibres pass internal to the vessels, and fade away posteriorly; the others run outside the vessels, quickly diminish in number, and disappear entirely at the level of the ora serrata.

The outer part of the sclerotic contains no elastic fibres, though the conjunctiva is rich in thick fibres that lie under its epithelial covering.

There is remarkably little elastic tissue in this eye.

Mistle Thrush—*Turdus viscivorus*. (Fig. 3.)

Descemet's membrane is thin and pale; it breaks up posteriorly and quickly fades away, to be succeeded by many scattered and somewhat coarse fibres having a circular course on the inner aspect of the canal of Schlemm, whilst on its outer aspect there is practically no elastic tissue.

The pectinate ligaments are thin, scattered, and do not fill the angle. The most anterior fibres go to the base of the iris, and after entering it run forwards for a short distance beneath its anterior endothelium; the others go to the ground plate of the ciliary processes, which contains few elastic fibres but many pigment cells. From the ground plate a few elastic fibres pass inwards into the ciliary processes, and others pass backwards towards the choroid.

The ciliary muscle is unaccompanied by elastic fibres, but is inserted, as usual, into an elastic bundle that divides posteriorly—to be inserted, on the one hand, into the perichondrium of the sclerotic cup, and on the other into the choroid, in which the greater number of fibres end somewhat posteriorly to the ora serrata (fig. 8).

The conjunctiva contains many elastic fibres circularly arranged that come into relation with a few fibres on the outer aspect of the sclerotic; these also are circular down to the level of the edge of the cartilage cup, beyond which their place is taken by arcuate fibres that extend backwards to the level of the ora.

Song Thrush—*Turdus musicus*.

Descemet's membrane does not stain, but elastic fibres spring at its posterior margin to form a network, the fibres of which are mostly circular in arrangement and are intermingled with arcuate white fibres with elastic

threads adhering to them. This network is confined to the part of the sclerotic that lies internal to the canal of Schlemm, the part outside it being quite devoid of elastic tissue.

The fibres of the pectinate ligaments are wholly elastic, spring from the sclerotic network, sweep across the angle and pass through the ground plate into the ciliary processes, where they end just under the uvea. Within the ground plate is an elastic network, the fibres of which pass backwards towards the choroid, but become obscured by the numerous pigment cells present among them; some of the fibres appear to extend to the insertion bundle of the ciliary muscle. This muscle takes origin from the fibrous tissue of the sclerotic, where few or no elastic fibres exist, and passes backwards to be inserted into the usual elastic bundle that bifurcates into two approximately equal portions, the one ending in the perichondrium of the cartilage cup, the other passing in the choroid on both sides of the vessels to end at the level of the ora serrata.

The conjunctiva contains many elastic fibres.

THE BLACKBIRD—*Turdus merula.*

Descemet's membrane is but faintly stained, but appears to possess an elastic facing which passes backwards to form a dense longitudinally stranded network from which the pectinate ligaments spring, and which extends in the sclerotic to the level of the posterior margin of Schlemm's canal after splitting to enclose it.

The pectinate ligaments are elastic, and continuous with the sclerotic network; they pass across the angle to end in the ciliary processes just external to the uvea.

The ciliary muscle arises from white fibres and is unaccompanied by elastic threads; it is inserted posteriorly into a bundle of arcuate elastic fibres that divides into two very unequal strands, the smaller of which terminates in the perichondrium of the cartilage cup, the larger entering the choroid and passing on both sides of the vessels to end near the ora.

The conjunctiva contains many elastic fibres, as does also the loose tissue surrounding the sclerotic.

EXPLANATION OF PLATES.

The sections were all stained with Weigert's elastic stain and mounted in balsam.

Figs. 1 to 5. Antero-posterior sections through the corneo-sclerotic junction of the eye of various birds. × 33.

Fig. 1. Domestic fowl—*Gallus.*

Fig. 2. Magpie—*Pica rustica.*

Fig. 3. Mistle thrush—*Turdus viscivorus.*

Fig. 4. Goldfinch—*Fringilla carduelis.*

Fig. 5. Common gull—*Larus canus.*

Fig. 6. Attachment of the fibres of the ciliary muscle to those of the elastic tendon. Eye of fowl × 290.

Fig. 7. Elastic network in the ground plate and elastic fibres of the ciliary processes. Eye of fowl × 290.

Fig. 8. Tendon of insertion of the ciliary muscle, showing its bifurcation posteriorly into two strands: the one passing to the choroid, and the other becoming attached to the perichondrium of the sclerotic cartilage cup. Eye of mistle thrush × 60.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4

Professor E. Wace Carlier.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

Professor E. Wace Carlier.

PIGMENTATION OF THE PIA MATER, WITH SPECIAL REFERENCE TO THE BRAIN OF MODERN EGYPTIANS.

By Wm St C. Symmers, M.B., *Aberdeen*; *Musgrave Professor of Pathology, Queen's College, Belfast.*

During the eight years which I spent in Egypt, I was repeatedly struck by the deep black pigmentation of parts of the central nervous system met with in the routine performance of post-mortem examinations at the Kasr-el Aini Hospital, Cairo. This condition was much more marked in Egypt than anything similar that I had observed in a large number of autopsies performed by me in Scotland and England.

The pigmentation varied in intensity from a smoky grey to jet black, and was most apparent on the lumbar and cervical enlargements, on the bulb, about the peduncles, and over the base of the brain, particularly on the optic chiasma and the orbital convolutions. The bulb was generally more deeply pigmented than the other regions. The pigment was contained in the pia mater.

English text-books of anatomy are silent as to this matter. *Quain's Anatomy*[1] alone mentions it, and disposes of it in a single sentence: "On the cord pigmented cells are sometimes scattered among the elastic fibres." In Fagge's *Medicine*[2] there is a footnote stating that the "normal pigmentation of the pia mater" has been found much intensified in Addison's Disease. I have recently, through the courtesy of Dr Elliot Smith, seen letters from Professor Obersteiner and Professor Gustaf Retzius in which both these observers refer to this pigmentation—the former expressly stating that it is frequently seen in Vienna, and both have described it in certain of their publications.[3] Moreover, there is an elaborate description of the condition by Charpy in Poirier's *Traité d'Anatomie Humaine*, 1894, tome iii. p. 121. The pial pigmentation of the sheep's brain, and to a lesser degree that of the Bovidæ, is well known

[1] *Quain*, vol. iii. pl. 1, p. 186.

[2] Fagge, *Principles and Practice of Medicine*, 1886, vol. ii. p. 509.

[3] Axel Key and Retzius, *Studien in der Anatomie des Nervensystems und des Bindegewebes*, 1875. Obersteiner, *Anleitung beim Studium des Baues der Nervosen Centralorgane*, 4 Aufl. p. 649.

to everyone. A somewhat similar state of affairs exists in the case of various monkeys, a fact of which I have been able to satisfy myself; and here again I am indebted to Dr Elliot Smith, who kindly allowed me to examine his collection of simian cerebra.

My early Cairo experience led me to believe that this pigmentation was more frequent and more intense in the native Egyptians (a light brown race) than in the black races, such as the negroes of the Sudan, the Berberines, and the Abyssinians. I therefore made careful notes as to this pigment in two hundred successive post-mortem examinations, with special reference to race, age, sex, cause of death, presence of parasites (*e.g.* Bilharzia and Anchylostomata), and weight of organs, particularly the Liver, Spleen, and Brain.

The subjects examined were:

1 Algerian Moor.	5 Armenians.
1 Bulgarian.	6 Berberines.
1 Bokhariot.	10 Greeks.
1 Abyssinian.	20 Sudanese.
2 Hindus.	148 Egyptians.
5 Turks.	

Among these the pigment was as follows:

In the	Algerian,	marked.
„	Bulgarian,	slight.
„	Bokhariot,	marked.
„	Abyssinian,	marked.
„	Hindus (2),	marked.
„	Turks (5),	very slight in 3, absent in 2.
„	Armenians (5),	very slight in 4, absent in 1.
„	Berberines (6),	slight in all.
„	Greeks (10),	marked in 1.
„	„	slight in 7.
„	„	absent in 2.
„	Sudanese (20),	marked in 5.
„	„	slight in 12.
„	„	absent in 3.
„	Egyptians (148),	marked in 77.
„	„	slight in 64.
„	„	absent in 7.

Leaving out those cases in which only one or two persons of a given race were examined, it appears that the pigmentation is most marked in the Egyptians. Probably this is a racial peculiarity.

I need not burden this paper with a detailed analysis of the two hundred post-mortem examinations. Suffice it to say that a careful consideration of the tabulated cases has convinced me that there is no specific relation between the pigmentation on the one hand, and, on the other, the age, sex, cause of death, etc. of the persons examined.

I conclude that the pial pigmentation is a normal occurrence, and that it is particularly marked in the case of Egyptians.

A CASE OF CONGENITAL ATRESIA OF PULMONARY ARTERY, WITH TRANSPOSITION OF VISCERA; A SECOND CASE OF TRANSPOSITION.

By JOHN McCRAE, M.B., L.R.C.P. Lond., *Lecturer in Pathology, M'Gill University, Montreal.*

(From the Pathological Laboratory, Royal Victoria Hospital, Montreal.)

THE congenital stenoses and atresiæ of the pulmonary artery together form the most numerous group of congenital heart lesions; but comparatively few of these are cases of absolute atresia, and a still smaller percentage is claimed by the cases where (as below) the pulmonary artery is represented by a fibrous cord. Of 82 cases of stenosis and atresia, 15 were atresic or showed the vessel represented by a solid cord (H. Meyer (1)); in general, it may be said that different authorities state that stenosis is three to eight times as frequent as atresia.

In any case of atresia, the expectation is that the ductus arteriosus will be found open, that in the great majority of cases there will be defect of the ventricular septum, and that in nearly as many there will be defect of the auricular septum. Stifel's (2) figures in cases of atresia are as follows: the artery is reduced to a string in 13 per cent.; the ductus arteriosus is open in 82 per cent.; the foramen ovale open in 61 per cent.; and there is defect of the ventricular septum in 76 per cent., the latter being commoner in atresia than in stenosis.

The particular combination of heart lesions under which the present case falls is that characterised by intact ventricular septum, patent auricular septum, and open ductus arteriosus.

Vierordt (3) quotes 12 cases of this, nearly all dying in the first week; in 1869, Peacock quoted 8 cases, which are probably incorporated in the twelve mentioned; Lordat's (4) case died at the age of six weeks, while Hare's lived 9 months. Among these cases there is one that anatomically closely resembles the case described below, namely, that of Ollivier (5).

If we approach the case from another standpoint—namely, that of its connection with transposition of the viscera—it may be pointed out that transposition of the vessels of the heart in various different ways is common, and by itself constitutes a group of congenital cardiac lesions; the transposition of the great vessels is often accompanied by valvular or

septal defects in the heart, and the complete transposition of not only the great vessels but also of all the viscera, together with a marked defect in the heart, will be readily seen to be a case differing only in degree.

Two cases are found in the literature available, where a defect of the pulmonary artery was combined with a transposition of the viscera; from the comparative frequency with which cases of transposition seen in life show some evidence of cardiac anomaly, it may be doubted if the combination is very rare, though actual figures are not available, nor is it possible in many cases to obtain post-mortem proof. Hickman's (6) case showed transposition of the lungs, liver, stomach, and spleen; the pulmonary artery was represented by a fibrous cord; the foramen ovale was patent, and the ventricles communicated: the child lived 6 weeks.

Wardrop Griffith's (7) case was 4½ months old, cyanosed in life, had complete transposition of abdominal and thoracic organs and at autopsy had a common ventricle, with imperfect division; the pulmonary artery was a fibrous cord, closely adherent to the aorta, traceable down to the ventricle; the lungs were supplied by the ductus arteriosus to two pulmonary branches, and by the enlarged bronchials; the suggestion is made that the left auricle had by pressure obliterated the pulmonary artery, and the observer points out that if the obliteration of the pulmonary artery occur after the completion of the ventricular system, the right ventricle becomes almost abolished, and the right auriculo-ventricular aperture diminishes in size. The present case showed such a diminution of the ventricle (see figure), but the orifice appeared to be of the usual dimensions.

Of the 12 cases referred to above as having an intact ventricular septum, Hare's (8) case (mentioned previously) was remarkable for the small size of the communication between the two auricles; the cavity of the right ventricle held a moderate-sized pea, the orifice of the pulmonary artery was closed, but the trunk communicated with the ductus arteriosus, and divided into the usual branches. Peacock's (9) case had free auricular communication; the pulmonary artery was pervious down to the valves: the child lived 9 days.

Before passing to the description of the cases, it may be noted that transposition of the viscera is a comparatively frequently-noted phenomenon: Arneill (10), in 1902, stated that probably more than 300 cases are on record; and, of course, many are observed during life and are not recorded. Thirty-three men, mostly clinicians, in answer to Arneill's enquiries, had seen 37 cases, of which 31 were observed in life. The autopsy records of the Montreal General and the Royal Victoria Hospitals, aggregating about 4000 cases, have shown but two: in addition

to these two, found at autopsy, I saw a living case in the wards of the Toronto General Hospital in 1898, but I regret that I have no notes referring to it; a case that lately attended the Royal Victoria Hospital was reported by Fry (11) in 1903, and it is there stated that the patient showed evidences of pulmonary stenosis. In going through the records of the Pathological Society of London, it is notable that Hickman was able to report at two successive meetings cases of transposition, each associated with a cardiac anomaly.

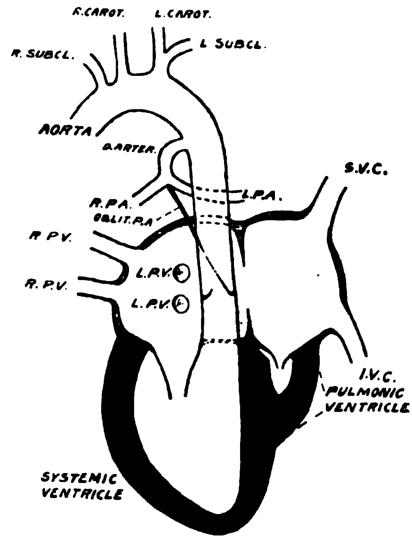
The transposition of both abdominal and thoracic organs is the rule, Gruber finding it so in 71 out of 79 cases: of the 8 cases where the abdominal organs only were transposed, all were incomplete (*cf.* gall-bladder of present case fails to be transposed). Steinhäuser states that there is very often some irregularity of the organs in abdominal transposition.

Case Report.

A male infant, 49 days old, came to autopsy from the Foundling Hospital, where it had been known as a "blue baby." It had been born at the Maternity Hospital, the fifteenth child of a 46-year-old mother, who was mentally dull, and showed no affection for the child. The mother had an unimportant family history: no abnormality is known to exist in any other of her children: the mother has a hare-lip, and has a systolic murmur audible widely over the chest. Before birth, a fœtal systolic murmur was demonstrated by Dr D. J. Evans to the students; and after birth this systolic murmur, basal in position, was heard throughout the child's life. The child was born at term, was very "blue" in colour, and always became more deeply cyanosed after feeding: it was large and well nourished.

At autopsy the body, 50 cm. long, was livid, well nourished, and the lungs showed bilateral broncho-pneumonia (the cause of death), with streptococci in smears. Transposition of all viscera was noted, with the exception of the gall-bladder. At first sight the heart appeared to be in its normal position, and its apex lay on the left side: this was afterwards found to be due to the anomalous formation, and the heart proved, on examination, to be completely transposed, as were the vessels. A bilobed lung was found on the right side, and a trilobed organ on the left: the greater part of the liver appeared on the left side, but the gall-bladder lay to the right of the umbilical vein and of the suspensory ligament of the organ: the bile duct lay to the left of the hepatic artery and the portal vein in its usual position behind, but inclining from right to left. The spleen lay on the right side, as did the stomach, the cœcum and appendix upon the left; the right renal vein received the spermatic vein.

The heart appeared at a superficial glance to be situated as usual, but, as stated, it was inverted. The innominate vein coursed from right to left, the innominate artery gave off the left carotid and subclavian, while on the right the vessels came from the aorta separately; the aorta ran down the right side, and the greater azygos vein up the left side of the median line. The heart, viewed from the front, showed only one great artery about 1·5 cm. diameter, and but one chamber was visible from the front; four-fifths of the ventricular bulk was taken up by one ventricle (the normal left, here situated on the right), and the pulmonic ventricle lay on it as a rounded boss, firm to the touch, reaching to within 1 cm. of the heart apex, which



was formed by the systemic ventricle alone. The systemic ventricle was large, of good musculature, and in every way enlarged: the pulmonic ventricle appeared to bulge into the other, but the septum was perfectly intact. The tricuspid valve appeared normal, while the cavity of the pulmonic ventricle was small, about 8 mm. diameter, having no outlet other than the tricuspid orifice. Its muscle was 6–7 mm. thick.

The venæ cavæ came in on the present left auricle (*i.e.* the auricle of the pulmonic side of the heart), and the veins from the lungs on the right; there were three pulmonary veins on the left and two on the right; the septum between the two auricles was represented by a flange of tissue, with a rounded, crescentic edge, abutting from the posterior surface and not serving to separate the two cavities in any degree, the patency being practically complete.

From the systemic ventricle comes off the aorta, from which the coronaries spring in the usual manner; the left coronary runs between the ventricles, and dips into the cleft at the base of the small rudimentary chamber, emerging from this cleft to run once more towards the tip of the systemic ventricle. The aortic valve consists of three cusps. At a point 2 cm. from the origin of the aorta arises the ductus arteriosus, which is 1 cm. long, 5 mm. diameter, and divides into the two arteries to the lungs. From the left of these two branches, close to the bifurcation, runs a cord, rounded and narrowest at its middle, which reaches down to the heart apparently to the upper surface of the pulmonic ventricle, thus taking the position of the (inverted) pulmonary artery. It is 1 mm. in diameter at its thickest, and no lumen exists, nor at either end can any probe or bristle be inserted which might lead to the proof of its being the remains of the pulmonary vessel. There is no reasonable doubt, from its appearance and position, that it is the completely obliterated pulmonary artery.

It will be observed that while the heart is embryologically a four-chambered one, it practically consists, for working purposes, of one auricular and one ventricular cavity. The great development, relatively, of the systemic ventricle on the right has displaced the smaller pulmonic ventricle towards the left, so that the greater bulk and the apex come to lie upon the left of the median line. It is probable that the systolic murmur heard over the base of the heart, was due to the small but strong pulmonic ventricle driving blood through the tricuspid orifice.

The specimen, of which the organs remain *in situ*, is in the Museum of the Medical Faculty, M^cGill University.

Anatomical Diagnosis.—Complete atresia of pulmonary artery, with fibrous cord; aplasia of pulmonic ventricle; deficient septum auriculare; open ductus arteriosus, supplying the lungs; hypertrophy of systemic ventricle; transposition of all thoracic and abdominal organs, with the exception of the gall-bladder; acute bilateral broncho-pneumonia.

Transposition of Viscera—Case II.

Anat. Diag.—Transposition of all thoracic and abdominal viscera: Acute lobar pneumonia.

The patient, a woman of about 40 years, was admitted, in April 1904, to the wards of the Montreal General Hospital: she was moribund, and died a few hours later. The autopsy, 24 hours after death, was hurried, and no photograph of the organs could be obtained; nor could the organs be preserved, as the consent of relatives was withheld. Death had occurred

from lobar pneumonia: the viscera were, without exception, transposed, observations being taken of heart, lungs, great vessels and branches, venæ cavæ, vena azygos major, liver, gall-bladder, pancreas, spleen, coccum, appendix, sigmoid flexure, rectum, relative height of kidneys and ovarian veins.

Note.—Since writing the above, the author was fortunate enough to find at autopsy a third case of transposition of viscera, which is reported in the *Montreal Medical Journal*, August 1905.

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ON THE HOMOLOGY AND MORPHOLOGY OF THE POPLITEUS MUSCLE: A CONTRIBUTION TO COMPARATIVE MYOLOGY.

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WHILE engaged in the dissection of a specimen of Felis domestica, our attention was attracted by the fact that the *lowest and most external fibres* of the popliteus muscle appeared to pass uninterruptedly into the tibialis portion of the deep flexor of the pedal digits; indeed, almost a third of the muscle joined the flexor tibialis (*vide* fig. 5).

On closer inspection, a minute tendinous intersection was found to be present in the muscular substance; but certain of the fibres undoubtedly passed into the more distal muscle without any interruption in their continuity.

The obvious suggestion was that these represented the *condylo-radialis* of Windle, which occurs frequently in the anterior extremity. Indeed, the attachment of the two muscles had a fair amount of similarity—namely, a muscular slip arose from the external condyle of the femur (the representative of the internal humeral condyle) and passed to join the flexor tibialis digitorum pedis—the representative of the flexor radialis of the forearm.

We decided to investigate this point by means of dissections of various types, but we found that the matter was more involved than at first sight appeared, and that a proper determination of the homology of this muscle necessitated a comprehensive morphological survey of the flexor group of muscles of the posterior tibial region, and, beyond this, a consideration of the homologies existing between them and the corresponding group in the fore limb.

In this endeavour, dissections have been made of the hind limb of the following members of the various mammalian orders, with the exception of

the Cetacea and Sirenia, in which a hind limb is either rudimentary or absent altogether.

Two specimens of lizard have also been investigated.

Reptilia.
- Lacertilia.
  - Varanus flavescens.
  - Varanus exanthematicus.

Mammalia.
- Monotremata.
  - Echidna hystrix (Spiny Ant-eater).
- Marsupialia.
  - Trichosurus fuliginosus (Sooty Phalanger).
  - Trichosurus vulpecula (Vulpine Phalanger).
  - Macropus melanops (Black-faced Kangaroo).
  - Hypsiprymnus rufescens (Rufus Rat Kangaroo).
- Edentata.
  - Bradypus tridactylus (Three-toed Sloth).
  - Dasypus villosus (Hairy Armadillo—two specimens).
- Ungulata.
  - *Cervidæ.* Cervus axis (Axis Deer).
  - *Bovidæ.* Ovis aries (Common Sheep).
    Ovis burrhel (Burrhel Wild Sheep).
    Gazella Arabica (Arabian Gazelle).
  - *Subungulata.* Hyrax Capensis (Cape Hyrax).
- Rodentia.
  - *Myomorpha.* Mus musculus (Mouse).
  - *Hystricomorpha.* Atherura Africana (African Brush-tailed Porcupine).
    Cavia cobaya (Guinea-pig).
  - *Lagomorpha.* Lepus cuniculus (Rabbit).
- Carnivora.
  - *Felidæ.* Felis domestica (Domestic Cat—several specimens).
  - *Viverridæ.* Suricata tetradactyla (Suricate).
    Herpestes griseus (Grey Ichneumon).
  - *Canidæ.* Canis familiaris (Dog).
    Canis vulpes (Fox).
  - *Ursidæ.* Ursus Malayanus (Malay Bear).
  - *Mustelidæ.* Lutra vulgaris (Otter).
- Insectivora.
  - Erinaceus Europæus (Hedgehog).
- Cheiroptera.
  - Cynonycteris collaris (Collared Fruit-bat).
- Primates.
  - *Lemuroidea.* Lemur catta (Ring-tailed Lemur).
  - *Anthropoidea.* Platyrrhini—Cebus fatuellus (Brown Capuchin).
    Catarrhini—Macacus rhesus (Rhesus Monkey).
    Papio porcarius (Chacma Baboon).

The following is a detailed account of the popliteus and upper attachments of the flexores tibialis et fibularis, as found in the dissections of the foregoing animals.

The lower attachments of the latter two muscles were only investigated in so far as was necessary to identify them.

FIG. 1.—Posterior tibial region of Varanus exanthematicus.

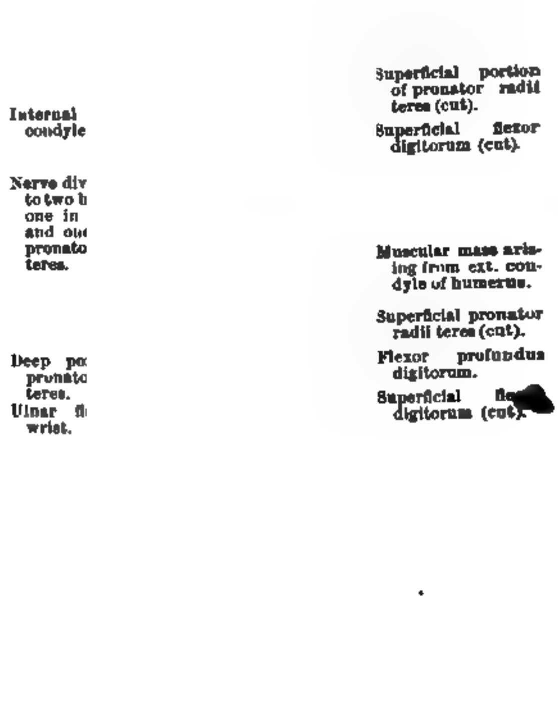

FIG. 2.—Varanus flavescens. Ventral surface of antibrachium.

RESULTS OF DISSECTIONS.

Varanus exanthematicus, Varanus flavescens (*vide* figs. 1 and 2).—In both of these forms the popliteus arises (1) from the head of the fibula, (2) from the meniscus femoro-fibularis; the latter attachment is only a slight one.

The meniscus femoro-fibularis is connected with the external femoral condyle by the ligamentum femoro-fibulare.

The muscle consists of fibres which may be somewhat artificially

separated into 2 layers. There is not, however, in our specimens the distinct separation between these 2 layers which Fürst figures in Varanus Gouldii. The *nerve passes superficial to the muscle.* No fibres of the popliteus

F.

Popliteus.

Tibio-fibularis.

F. tibialis.

FIG. 3.—Echidna hystrix.

pass into the flexor muscle of the digits. Both flexor tibialis and flexor fibularis arose from the head of the fibula.

Echidna Hystrix.—The popliteus is attached above to the mesial aspect of the processus capituli fibularis, and below to the upper half of the tibia. There is a deeper stratum of transverse fibres, which Fürst calls the "pars

interossea" as opposed to the "pars propria." This is certainly a separate interosseus muscle, the "tibio-fibularis." It constitutes the third or deepest muscular stratum of the leg.

The tibialis portion of the deep flexor of the digits arises from the tibia below the popliteus insertion, but no fibres of the latter muscle pass into the flexor tibialis.

The flexor fibularis has the usual origin from the upper part of the fibula (*vide* fig. 3).

Trichosurus fuliginosus.—From the upper extremity of the fibula there arises a stratum, which consists of the following muscles—in order from above downwards, and from within outwards: (1) Popliteus; (2) a fasciculus, intimately associated with the popliteus at its origin, but passing below directly into the flexor tibialis; (3) flexor tibialis; (4) tibialis posticus; (5) flexor fibularis.

(2) and (3) are separated by the nerve-twigs proceeding to supply the popliteus.

The flexor tibialis ends in a sesamoid in the sole of the foot.

The flexor fibularis supplies all the digits, and also gives off from its superficial aspect in the middle of the leg the superficial flexor of the toes (*vide* fig. 4).

Trichosurus vulpecula.—The arrangement of muscles of the hind limb is the same as in T. fuliginosus; but the flexor fibularis does not give origin to the superficial flexor, as in the other species.

Macropus melanops.—Popliteus arises (1) from the external femoral condyle by means of a strong tendon; (2) from a sesamoid developed in the aforesaid tendon; (3) from the head of the fibula, slightly. The insertion is into the upper fifth of the tibia.

From the superficial aspect of the muscle near its inferior border a muscular slip takes origin, of which the fleshy belly, measuring about 1¼ inches in length, passes into a long filiform tendon which is attached to the tarsus. The direction of the muscular fibres in this slip corresponds with that of the popliteal fibres.

The flexor fibularis is a powerful muscle arising from fibula and tibia, and supplies all the 4 digits.

The long tendinous slip, with the fleshy belly at its proximal end, would appear to be a flexor tibialis, because of its superficial position, for a tibialis posticus would not be superficial to the popliteus. Its insertion into the tarsus is not an insurmountable objection, for the flexor tibialis may end in the tarsus in certain rodents, and it ends in a sesamoid in the phalangers.

If the slip referred to be the flexor tibialis, then *no* tibialis posticus is present.

Hypsiprymnus rufescens.—The popliteus arises from external femoral condyle. There is the usual insertion.

The flexor fibularis is a powerful muscle, and, as in Macropus, arises from tibia and fibula.

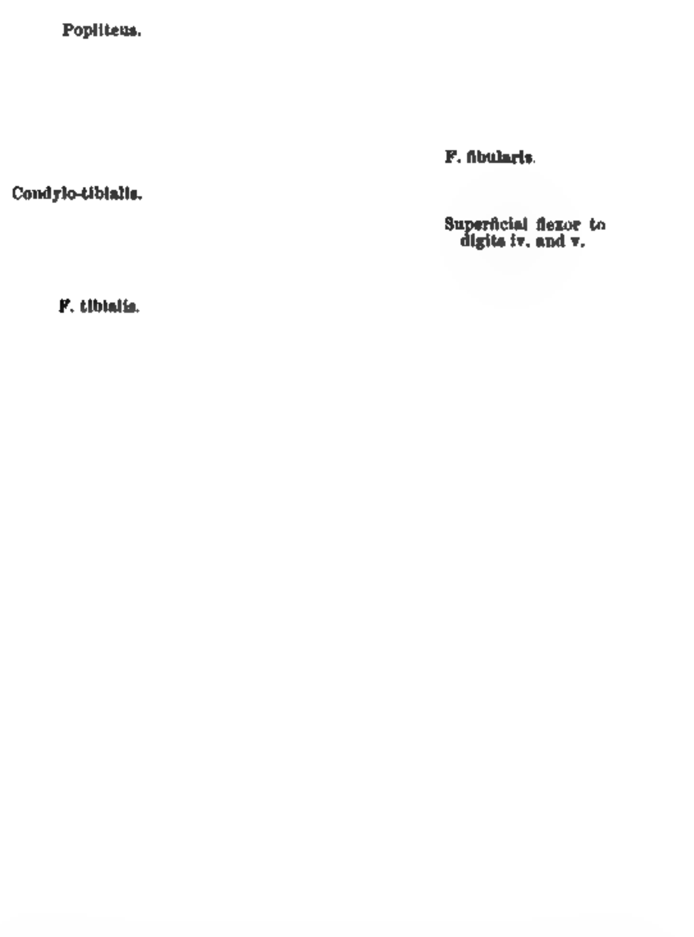

FIG. 4.—Trichosurus fuliginosus.

The tibialis is a similar minute fleshy slip, with a filiform tendon, but does not arise from the superficial aspect of the popliteus, but, running along the lower border of the latter muscle, it can be traced up to the fibular head. It ends as in Macropus, on the tarsus.

Bradypus tridactylus.—The popliteus arises from the external femoral condyle, and is inserted into the upper two-thirds of the tibia. No fibres pass into the flexor tibialis, but a muscular bundle of considerable dimensions arises from the external supracondylar ridge of the femur, proximal to the origin of the external head of the gastrocnemius. This passes down the limb, deep to the last mentioned muscle, and joins the flexor fibularis on its superficial and inner aspect.

Dasypus villosus.—The popliteus arises from the external condyle of the femur; it is inserted into the upper half of the tibia. The flexor fibularis is a very powerful muscle. The flexor tibialis is smaller than the fibularis, and arises (1) from the tibia; and (2) some of the lowermost and outermost fibres of the popliteus pass into the muscle.

Cervus axis.—The popliteus arises from the external condyle of the femur, and is inserted into the upper third of the tibia. Some of the lower and outermost fibres gain an attachment to a tendino-aponeurotic band on the external and deep aspect of the uppermost part of the flexor tibialis.

From this tendinous band, some of the fibres of the flexor tibialis also arise.

This arrangement obtains in our other ungulata, viz.—Gazella Arabica, Ovis aries, and Ovis burrheli.

Hyrax Capensis.—The popliteus arises from the external femoral condyle, and has the usual insertion. No fibres pass into the flexor tibialis, which is distinctly smaller than the flexor fibularis. There is no tibialis posticus.

Mus musculus.—No popliteal fibres pass into the flexor tibialis.

Atherura Africana.—The popliteus arises from the external femoral condyle, and is inserted into the upper third of the tibia. A small fasciculus passes into the flexor tibialis. Flexor fibularis is a large muscle arising from both tibia and fibula. Flexor tibialis is comparatively small. A tibialis posticus is present.

Cavia cobaya and *Lepus cuniculus* show no trace of popliteal fibres passing into flexor tibialis.

Felis domestica.—The popliteus arises from external femoral condyle. The tibialis has three heads of origin: (1) a tibial head; (2) a fibular head; (3) a popliteal head.

The size of this latter head appears to vary. In the first specimen that we dissected, a very large proportion of the muscle passed with the popliteus to the external femoral condyle; but in subsequent dissections of other specimens the size of this head was much smaller, or did not exist at all.

The fibularis and tibialis posticus each arises by two heads, from the fibula and tibia respectively (fig. 5).

Suricata tetradactyla.—The popliteus arises from the external femoral

Popliteus.

Condylo-

Fibular head of flexor tibialis.

Tibial head of flexor fibularis.

F. fibularis.

F.

Double-headed tibialis posticus.

Fig. 5.—Felis domestica.

condyle, and is inserted into the upper two-thirds of the tibia. Its outermost and lowest fibres are directly continuous with those of the flexor tibialis.

The flexor fibularis is the largest muscle of the flexor stratum.

Herpestes griseus and *Canis familiaris* show no trace of popliteal fibres passing into the flexor tibialis.

Canis vulpes.—A similar condition obtains here.

Ursus Malayanus.—The popliteus arises from the external femoral condyle. The muscle is inserted (1) into the upper half of the posterior surface of the tibia. (2) Some of the outer and deeper fibres are inserted into the tibial half of a tendinous band, running from fibula to tibia, along the

Poplit
and
iteal sesamoid
tor fibulæ.
ularis
lis posticus.
F. fibularis.
Tibialis posticus.
Popliteus.
Condylo-tibialis.
F. tibialis.

FIG. 6.—Lemur catta.

FIG. 7.—Posterior tibial region of macacus rhesus.

upper border of the tibialis; the flexor tibialis arises from tibia, head of fibula, and the tibio-fibular tendinous band referred to.

Lutra vulgaris.—The popliteus arises from the external femoral condyle, and inserted into the upper half of the tibia.

The tibialis arises as in Ursus, but in addition some fibres are attached to some tendinous bundles on the lower border of the popliteus.

The tenuissimus emerged from the postero-inferior border of the flexor cruris lateralis, and extended right down to the os calcis, remaining fleshy to within a third of an inch of its insertion.

Erinaceus Europæus.—No fibres of popliteus passed into flexor tibialis.

Cynonycteris collaris.—A popliteus was not present. Fürst also failed to find it in a Pteropus and a Vespertilio.

Lemur catta.—The popliteus comes from the external femoral condyle, though at first sight it appears to arise from the fibular sesamoid; but the tendon can be distinctly traced onwards underneath the external lateral ligament, to the external condyle. The tendon appears to be degenerate.

The sesamoid is closely bound to the head of the fibula.

Beneath the popliteus is a rotator fibulæ, which stretches across the uppermost part of the interosseous space. This muscle is evidently a persistent portion of the primitive interosseous muscle, known as the tibio-fibularis. No popliteal fibres pass into the flexor tibialis (*vide* fig. 6).

Papio porcarius.—The popliteus arises from the external femoral condyle; a few of its lowermost fibres are continuous with the flexor tibialis, a minute tendinous intersection intervening.

Macacus rhesus and *Cebus fatuellus* show a similar arrangement, but no tendinous intersection appears to be present (*vide* fig. 7).

The results of our dissections may be briefly expressed as follows:—There is intimately associated with the popliteus a distinct band of muscular fibres whose upper attachment varies *pari passu* with that of the popliteus, and which passes below into the flexor tibialis.

Such a muscular slip is *present* in the following animals:—

Marsupialia.	Trichosurus fuliginosus.
	Trichosurus vulpecula.
	Macropus melanops.
	Hypsiprymnus rufescens.
Edentata.	Dasypus villosus (2 specimens).
Rodentia.	Atherura Africana.
Carnivora.	Felis domestica (some specimens).
	Suricata tetradactyla.
Primates.	Cebus fatuellus.
	Macacus rhesus.
	Papio porcarius.

It is doubtfully present in the following:—

All the Ungulata, except hyrax.

Carnivora.	Ursus Malayanus.
	Lutra vulgaris.
	Felis domestica (some specimens).

It is entirely absent in the following:—

Lacertilia.	Varanus flavescens.
	Varanus exanthematicus.
Monotremata.	Echidna hystrix.
Edentata.	Bradypus tridactylus.
Ungulata.	Hyrax Capensis.
Rodentia.	Mus musculus.
	Lepus cuniculus.
	Cavia cobaya.
Carnivora.	Canis familiaris.
	Canis vulpes.
	Herpestes griseus.
Insectivora.	Erinaceus Europæus.
Chiroptera.	Cynonycetoris collaris.
Primates.	Lemur catta.

The Primitive Proximal Attachment of the Muscles of the Posterior Tibial Region.

In the *hind limb of the lizard* it will be remembered that *not only did the popliteus arise from the fibula*, but that the *flexor tibialis arose from the fibula as well*, there being, paradoxical as it may appear, no origin of the F. "tibialis" from the tibia (*vide* figs. 1 and 2).

A dissection of the same region in the fore limb revealed the same interesting condition, viz.—That the *flexor "radialis" arose entirely from the ulna*, there being *no* radial origin to this muscle. In the fore limb the superficial flexor (sublimis) arose as usual from the internal condyle, so that we have the very suggestive fact that *both superficial and deep flexors arose from the post-axial side of the limb.*

We believe this to be the primitive arrangement in both the forearm and leg regions, and we suggest that it is correlated with a caudal-ward movement at the elbow-joint and knee-joint necessary for the method of progression by sprawling or swimming, which obtains in the lower vertebrata.

Homology of the Popliteus.

It is usually stated that the popliteus is the homologue of the pronator radii teres. Keith, however, in his *Myology of the Catarrhini* puts forward the suggestion that it represents the *deep part only* of this muscle, and that the superficial portion may be represented in man by an occasional slip from the external head of the gastrocnemius.

Hepburn has found a similar slip in the chimpanzee.

With Keith's suggestion we entirely concur. In dissecting the fore-limb of our two specimens of Varanus, we found that the *pronator radii teres was composed of two distinct parts*:—

(1) A superficial portion arising from the internal condyle.

(2) A deep portion arising from the upper part of the shaft of the ulna, close to its head.

The median nerve passed between these two portions, whilst the anterior interosseous nerve passed downwards behind a deep portion, embedded in the substance of a well-developed interosseous radio-ulnaris muscle (*vide* fig. 1).[1]

In the hind limb of Varanus, the popliteus arose as before stated from the head of the fibula, and was inserted into the tibia in its upper half. Beneath it was the interosseous layer of muscle, known as the tibio-fibularis, and it was covered by the superficial mass of flexor muscles with which it, as well as the flexores tibialis et fibularis, were intimately connected (*vide* fig. 2).

It will be seen then that the popliteus of Varanus exactly *corresponds*, both in origin, insertion, and relations, with the *deep portion* of the *pronator radii teres*. The superficial of the latter muscle is probably represented in the hind limb of Varanus by some of the fibres of connection which exist plentifully between the superficial and deep layers of muscle, and which, arising in common with a gastrocnemius mass, attain an extensive aponeurotic insertion into the inner border of the tibia.

From a consideration of all the foregoing facts it is obvious that the popliteus belongs to the same stratum as the F. tibialis et fibularis, and that it is a differentiated part of the muscle-sheet, which also gives rise to the F. tibialis and F. fibularis.

Moreover, we have seen in the lizard how this muscle-sheet is primitively post-axial at its proximal attachment.

In the fore limb also the corresponding muscle group—that is, the *deep* portion of the pronator radii teres, and the F. radialis et ulnaris—are likewise post-axial in origin.

The Phylogenetic Variations in the Upper Attachment of the Popliteus.

In a primitive limb, as in Varanus, the tibia and fibula move freely upon one another; indeed, the need of some means of attaining the rotatory movements of the limb necessary for propulsion or progression is probably

[1] Since writing the above, we have examined the dissections of the antibrachium of Ornithorhyncus anatinus and Echidna aculeata in the Museum of the Royal College of Surgeons, and were much interested to find that an *ulnar* head to the pronator radii teres exists in both of them.

the factor which has determined the existence of two bones in the middle segment of either limb. *When the necessity for such a movement is no longer required, the bones tend to become fused.* Coincidently with the loss of movement between the tibia and fibula, changes in the muscle will inevitably follow. Rotatory movement between the two bones of the leg is absent in the majority of the mammalia, and is confined (if one except the case of the Lemur) to the *Monotremes and less specialised members of the Marsupialia.*

It is an interesting and suggestive fact that the rotatory mechanism seen in the lizards should be retained in these early and primitive mammalian orders.

In Echidna hystrix, and in both our specimens of Trichosurus, there was free movement between the bones of the leg; and in Echidna of the fibula on the femur, and in all the popliteus, had only a fibular (post-axial) attachment in the same manner as obtained in Varanus. The musculature of these mammals in the region under discussion only differed from that of the reptile in that the F. tibialis did not have a purely fibular origin (*cp.* figs. 1, 3, and 4).

The proximal attachment of these muscles in the leg of the more generalised Marsupials is therefore very fairly comparable with those of the homologous muscles in the antibrachium, as they exist in man.

In the highly specialised Marsupials, *e.g.* Kangaroo, and in all the remaining orders (except the sub-order of the Lemuroidea or Lemurs), the pseudo-rotatory movement between the leg bones has become lost, and coincidently the popliteus having ceased to perform its original function as a fibular rotator, has become modified to act as a flexor of the leg, and has in consequence *acquired a new attachment to* the external condyle of the femur by *ascent.*

In the Kangaroo, the F. fibularis is the only functional deep flexor of the digits present, and the F. tibialis appears to be reduced to the small muscle arising from the superficial aspect of the popliteus, which has already been described.

In the ungulates, the popliteus has distally a very characteristic mode of attachment—viz., to the upper edge of a fibrous arch, passing between the fibula and tibia.

This arch corresponds in position with the line of attachment of the human soleus, and we suggest that, in the case of Man, the soleus has extended along this arch from its primitive fibular origin until it has reached the tibia, thus cutting off the popliteus from the flexor tibialis, and at the same time pushing the latter muscle down on to the tibia, so that it no longer has a fibular head.

THE POPLITEAL FABELLA.

A fabella was developed in the tendon of the popliteus in most of the animals dissected by us, with the exception of the ungulates, and those animals in which it arose from the head of the fibula.

The fabella would therefore appear to be connected in some way with the ascent of the upper attachment of the muscle. It is developed from the fibro-cartilaginous ligamentum femoro-fibulare of Fürst, which in the lizard passes from the head of the fibula to the external condyle, and which the muscle in other forms utilises to attain its femoral attachment.

It scarcely appears likely to have been formed as a separated traction epiphysis of the head of the fibula, after the manner of fabella formation described by Parsons in the tendons of certain other muscles.

THE POPLITEUS OF THE LEMUR. (*Vide* fig. 6.)

The exceptional condition found in this animal requires special reference. The popliteus arises from the external condyle through a broad, flat tendon, which joins the muscle by the medium of a well-marked sesamoid, and which is very closely adherent to the head of the fibula.

Underneath the muscle is, as we have seen, a broad band of muscle fibres known as the rotator fibulæ. This muscle is not a part of the deep flexor sheet of which the popliteus represents a differentiated portion, but is to be regarded, as we have already stated, as a *persistent upper part of the interosseous tibio-fibularis of lower mammals*. To regard the popliteus as consisting of two strata independent of the tibio-fibularis, is to imply the existence of *four* primitive muscle strata in the leg, because we have already stated that we regard a portion of the gastrocnemius mass as equivalent in the lower limb to the superficial portion of the pronator radii teres in the upper limb.

It is very interesting to observe that in this animal, which alone of all the higher mammals manifests fibular rotation, the popliteus appears to be preparing through the sesamoid to redescend on to the fibula, doubtless to fulfil thereby the function of rotation, which is characteristic of the muscle in the primitive limb.

MORPHOLOGY OF THE "CONDYLO-TIBIALIS."

As stated on the opening page of this paper, our original intention was to ascertain the constancy of this slip in the various mammalian orders, and, if possible, to decide with what muscle of the fore limb it is homologous.

It would appear to us that its homologue in the anterior extremity is

the condylo-radialis of Windle. Professor Windle (*Journal of Anatomy and Physiology*, N.S., 4, 1899-90) has pointed out that the flexor mass of muscle in the forearm may be regarded as typically consisting of the following 6 parts—viz., flexor sublimis, flexor radialis, flexor ulnaris, condylo-radialis, condylo-ulnaris, and condylo-centralis.

Excluding the sublimis, the deep flexor will therefore consist of 5 parts, in a generalised mammal, such as a Carnivore or Insectivore. After the radialis and ulnaris, the commonest constituent is the condylo-radialis, which, according to Windle, arises typically from the internal humeral condyle, and joins the radial side of the common tendon, formed by the various components of the deep flexor stratum. A comparison between the condylo-tibialis and condylo-radialis shows that, not only do they bear a similar relation to the popliteus and deep portion of the pronator radii teres respectively, which, as we have seen, are to be regarded as homologous, but that they accompany the phylogenetic migrations of these muscles in a striking manner.

It is clearly apparent that there are certain stages in the phylogeny of the muscles derived from the deep flexor sheet of the forearm and of the leg.

The *first stage* is one in which the popliteus, flexor tibialis, and flexor fibularis all arise from the fibula, whilst in the forearm the *deep head* of the pronator radii teres, the radialis, and ulnaris all take origin from the ulna; such a stage is seen in the anterior and posterior extremities of the Lacertilia.

In the *second stage*, the other crural and antibrachial muscles retain their primitive attachments, but the flexor tibialis and flexor radialis extend their origins to the tibia and radius respectively. This condition is present in the Monotremata in both limbs, but in generalised Marsupials in the *leg* only, the muscles of the upper limb having passed into the third stage.

In the *third stage*, movement between the tibia and fibula having ceased to exist, the popliteus ascends to the external condyle of the femur, and carries with it some of the fibres of the flexor tibialis which represent the condylo-tibial slip under discussion; in the preceding stages, where the tendon of origin has not ascended to the outer condyle of the femur, the slip must be regarded as representing the connecting fibres with the flexor tibialis, which, in the primitive condition, extended continuously along the posterior aspect of the leg. In the antibrachium, though we cannot say definitely that the deep head of the pronator radii teres ascends to the internal condyle when movement between the bones ceases to exist, yet it is highly probable that some of the deeper fibres of the pronator radii teres in Carnivores, which undoubtedly arise from the internal condyle, represent the original *ulnar head* of the muscle; for it is noteworthy that the pronator

radii teres in the Cat is a deep, wedge-shaped muscle, extending right down to the upper extremities of the two bones of the forearm. None of the deep flexor layer of muscle extends beneath the pronator, and in thickness it certainly equals the conjoined superficial and deep flexor mass.

With this probable migration of the deep head of the pronator radii teres, the condylo-radialis is carried up also, to gain an attachment to the internal condyle.

But if such be the march of events, and if from the phylogenetic point of view the humeral origin of the condylo-radialis be more recent than the ulnar origin, then it may be objected that it appears rather strange that in Man, a mammal most specialised and the most highly evolved, the apparently older stage in the evolution of the muscle persists.

But we must remember that, in him, movement between the bones of the forearm has reappeared in an extreme degree.

Obviously, muscles producing this movement will act to greater advantage if the ulna be their fixed point of attachment; and hence the fact that a reptilian characteristic—viz., the deep layer of the pronator radii teres—has in him reappeared.

The human condition then constitutes a *fourth stage* in the phylogeny of the muscles derived from the deep flexor sheet of the antibrachium, and may be regarded as a reversion to a more primitive stage in adaptation to special requirements.

In the leg of the Lemur, in which movement between the bones has been similarly reacquired, *indications of this fourth stage* are apparent in the firm attachment that the popliteus attains to the head of the fibula, by the medium of the popliteal sesamoid.

In this fourth and reversionary stage, as seen in the arm of Man, the condylo-radialis descends to the coronoid process of the ulna, with the deep portion of the pronator radii teres, and exists as the accessory head of the F. longus pollicis, being thus strictly comparable to the condition of the condylo-tibial slip in those animals in which the upper origin of the popliteus is from the head of the fibula (see figs. 3 and 4).

The condylo-radialis in the antibrachium is always closely related to the flexor sublimis digitorum.

The condylo-tibial slip in the leg of the generalised Marsupials which we have dissected, and in which the popliteus arose from the fibula, always took origin in close relation with that of the soleus, which is generally looked upon as the representative of the flexor sublimis digitorum of the fore limb.

This we look upon as further evidence that the slip in question is the homologue of the condylo-radialis in the forearm.

Conclusions.

(1) That the superficial portion of the pronator radii teres is homologous in the lower limb with a portion of the gastrocnemius mass.

(2) That the deep portion of the pronator radii teres is homologous in the lower limb with the popliteus.

(3) That the deep portion of the pronator radii teres and popliteus arose primitively from the head of ulna and head of fibula respectively.

(4) That as movement between the tibia and fibula, and radius and ulna respectively, ceased to exist, the upper origin of the popliteus certainly, and the deep portion of the pronator radii teres probably, ascended to the external femoral and internal humeral condyles respectively.

(5) That in this upward migration they carried with them certain fibres of the flexor tibialis and flexor radialis respectively.

(6) That these fibres exist as the condylo-tibialis and condylo-radialis respectively.

(7) That in the Lemur, where movement between the tibia and fibula has reappeared, the popliteus appears to be descending to its primitive fibular attachment.

(8) That in Man, and to an extent in the Anthropoid Apes, in whom movement between the radius and ulna has reappeared, the deep portion of the pronator radii teres has descended to its primitive ulnar attachment, carrying with it the condylo-radialis

(9) That the fibrous arch from which the soleus arises in Man, is identical with the similar structure to which, in Ungulates, a large portion of the popliteus is attached, and is to be regarded as indicating the original line of the fibular origin of the popliteus.

We cannot conclude this paper without expressing our thanks to Mr Beddard, of the Zoological Society of London, for his kindness in placing so many specimens at our disposal.

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THE FACIAL EXPRESSION OF VIOLENT EFFORT, BREATHLESSNESS, AND FATIGUE. By R. TAIT M'KENZIE, M.D., *Professor of Physical Education, U. of P., late Lecturer on Anatomy, M'Gill University.* (With illustrations from masks modelled in clay by the author—PLATE XIV.)

THE cinder-path and the campus offer a rich field for the observation of certain forms of facial expression which have been hitherto but little studied and ill understood.

It is impossible for a runner in the fierce struggle of a hundred-yard race to wear the look of indifference when he is trying by the use of every muscle, however weak and indirect its action may be, to increase, even by the smallest fraction, the length of his stride or quicken the speed of his movement. This effort is mirrored in his face with unfailing accuracy.

At the start of a hundred-yard dash the runner catches his breath, and usually holds it during the entire race if closely pressed. During this time the body is under stress of the most violent action, the great muscle masses of the legs are in powerful alternate contraction, and the torso is pulled and compressed by the vigorous action of the arms. The shutting of the glottis gives a more solid *point d'appui* for the muscles of the arms and shoulders, but it increases enormously the pressure on the heart and lungs. This increase in blood-pressure shows in the purple and swollen face and the red suffused eyes, in the lips retracted from the clenched teeth and the muscles of the neck fixed in contraction. This peculiar characteristic expression is also seen in jumpers, hurdlers, hammer-throwers, and football players. It indicates the acme of any violent effort.

From the study of many instantaneous photographs of athletes at work, and the observation of men in action at many athletic gatherings, the typical expression has gradually shaped itself in my mind, somewhat as appears in the accompanying mask (fig. 1). In modelling it, no one man or photograph has been exclusively followed, the endeavour being to combine what was characteristic in many, so as to show the typical face of violent effort.

In this face there is a general converging of the lines to the root of the nose, the transverse wrinkles at that point marking the action of the

pyramidalis nasi. The frowning brows are drawn down, and the palpepral fissure is narrowed to a mere slit. The outer angle of the eye shows the crow's-feet that accompany the strong action of the orbicularis palpebrarum. The sneering expression of the nose, caused by the action of the compressor nasi, is like the snarl of a dog, while the levator anguli oris exposes the canine tooth and increases the effect. The nostril is distended, the upper lip is raised from the teeth, and the direction of the naso-labial fold is altered. The lower lip is drawn tightly across the clenched teeth, except at the corners of the mouth, where it is pulled away by the platysma, leaving little pouches at each angle. The general impression of the face is repulsive. Hatred, menace, and rage predominate, with a feeling of distress about the strained mouth and neck.

In his description of rage, Darwin says, "The lips are much more commonly retracted, the grinning or clenched teeth being thus exposed. The appearance is as if the teeth were uncovered, ready for seizing or tearing an enemy, though there may be no intention of acting in this manner."

The drawing called "Rage," in Sir Charles Bell's classic work on expression, shows a face that corresponds closely to strain. The bent brows, wrinkled nose, and swollen eyelids, the snarling nose and cheek and lifted lip-angle, all suggest violent effort; the lower lip is also drawn down and the teeth exposed, but the staring eyes in his drawing are in contrast to the narrowed eye-opening characteristic of effort, while the raising of the upper lip-angle in Bell's drawing is unaccompanied by the strong retraction of the lips, that always marks embarrassed respiration.

Hogarth, one of the keenest observers of the human face in all its moods, is rich in studies of curious expression. In his picture of a cock-fight, he shows the face of a man on whom snuff has just been sprinkled from the open box of a spectator seated above him. He is raising his handkerchief to his nose, his face shows unmistakably that a sneeze is imminent, the lines converge to the root of the nose as in the mask, the action of the orbicularis being well shown in the tightly shut eyes.

This shutting of the eyes in all violent effort, such as shouting, sneezing, crying, or laughing, is explained by Bell as a protection against increased intra-ocular blood-pressure, which might rupture some of the more delicate of the distended vessels. Undoubtedly the runner would shut his eyes if he could, and the hammer-thrower occasionally does so at the moment of the greatest effort; but the runner must keep his course, and so the eye-openings are merely narrowed as much as possible.

The expression of the mouth is due to the drawing up of the lip and to the action of the platysma. The action of this muscle is very constant

in all forms of effort when the breathing is impeded, and it often springs into action when delivering a blow of the fist, or even in testing the grip by a hand dynamometer. It intensifies such an expression as surprise to astonishment or horror, of pain to torture, and of dislike and hatred to rage and fury. It might appropriately be called the muscle of emphasis.

When effort is prolonged to the point of breathlessness, as is seen in the continuous strain of a half-mile race, the facial expression becomes radically changed. The onset of this condition is marked by a quickening of the circulation, the eye becomes bright, the face ruddy, and the skin flushed. The breathing becomes deeper and more rapid, and a warm glow is felt throughout the body. As the waste matters accumulate in the circulation, the lungs begin to lag in their effort to throw them off, the breathing becomes more hurried, shallow, and spasmodic; a vague discomfort is felt, rapidly increasing to acute distress; there is a sense of constriction in the chest, murmurs and singing in the ears, flashes before the eyes, and mental confusion and even unconsciousness. When in this condition runners may swerve from their course, fall, run blindly into obstacles, or do other unaccountable things.

If we can believe the legend of Ladas the Spartan, we have at least one case of death from breathlessness, and it is not infrequent to have men faint at the end of a hard race; and even before the finish one occasionally sees the face become dusky and leaden, the lips blue and livid, the breathing shallow, and the man fall fainting before reaching the goal.

This respiratory madness, this distress of mind and body, is always pictured on the face of the struggling man.

In this mask (fig. 2) we have the typical face of the breathless man. The smoothness of the forehead is broken by wrinkles spreading out from the inner end of the updrawn eyebrows, where the general direction is just the reverse of that seen in violent effort; they are drawn upward and inward by the corrugator supercilii, the muscle of pain, which always acts in grief, mental distress, anxiety, and bodily pain. The differentiation of these various shades of expression will depend on the prevailing cast of the rest of the countenance.

The upper lids, in breathlessness, droop and half cover the eye, giving a look of great lassitude to the suffering expressed by this region of the face. The nostrils are widely dilated, the mouth gapes, and the lips are retracted in the mad struggle for air. The raised upper lip and the deepened and changed naso-labial fold add to the look of sorrow and pain, while the down-drawn mouth-angle, the tongue close pressed against the teeth, the cheek sunken into the cleft between the opened jaws, all go to increase the gasping, haggard look that is so characteristic of this state, in distinction

to mere bodily pain or mental suffering. The general pose of the head is backward, with the chin thrust forward and the neck usually convulsed by the sterno-mastoid and platysma and the other extraordinary muscles of respiration.

"In bodily pain," writes Sir Charles Bell, "conjoined with distress of mind, the eyebrows are knit, the pupils are in part concealed by the upper eyelids, and the nostrils are agitated."

Good examples of this condition are to be seen in Jean Paul Cortot's statue, "The Soldier of Marathon," in the Louvre; and in a drawing by Andrea Mantegna of the death of Antæus, the characteristic lines of breathlessness or suffocation are depicted in his face and neck as he gasps in the crushing embrace of Hercules, who holds him in mid-air.

The face of Laocoon struggling in the coils of the serpent has many of the characteristics of breathlessness in it. The swelling chest, the distended veins, and the swollen, contorted neck all combine to show that the struggle has left him breathless. Mingled with this there is pain and anxiety. The eyes are upturned, and the mouth is open and panting. He has been described by some writers as bellowing like a bull, and as crying out in his agony; but the knitted brows and the retracted lips, the extended head and the heaving chest, can be completely accounted for by the breathlessness of the strain and tug of the fight.

Breathlessness, as seen in the runner, would have mental anxiety associated with bodily distress, and the typical expression would correspond closely with the description quoted from Sir Charles Bell, with the addition of the gaping mouth and expanded nostrils.

With the re-establishment of the equilibrium between the production of waste and its elimination, the urgency of breathlessness passes off. The runner gets what is called his second wind, and the look of distress disappears from the face. The lungs feel as if they had regained their power to expand, and a crushing weight seems to be lifted from the chest. The head becomes clear again, and the muscles act with renewed vigour and elasticity. Soon after the relief felt by getting his second wind, the runner begins to notice a general sensation of lassitude creeping over him. His muscles become slower and slower in responding to the will, each effort requires greater and greater concentration of attention and force of will, and his lassitude gradually deepens. Group after group of muscles refuse to continue their work, until he staggers along with relaxed grip, yielding ankle, fallen jaw, and closing eye.

In this mask (fig. 3) we see the typical face of fatigue after the urgency of breathlessness has passed off. The eyebrows show a slight frown, and the eyelids are heavy as with sleep. The upper lip is still retracted

irregularly from the teeth, giving a slight look of pain to the cheek, which is otherwise relaxed and flaccid. The mouth is half open, and the lower lip hangs loosely from the parted teeth. The eyebrows have just such an appearance in deep thought, painful attention, as when listening to an indistinct speaker or watching a distant object in an uncertain light. The general effect is one of vacancy. Such a stupid, vacant look is well depicted by Hogarth in some of his pictures of drunkenness, notably one figure in "A Midnight Modern Conversation," the chief differences being that the drunken man has a vacant, silly smile about the mouth, which in the mask of fatigue is replaced by slightly retracted lips and a trace of pain about the mouth and cheek.

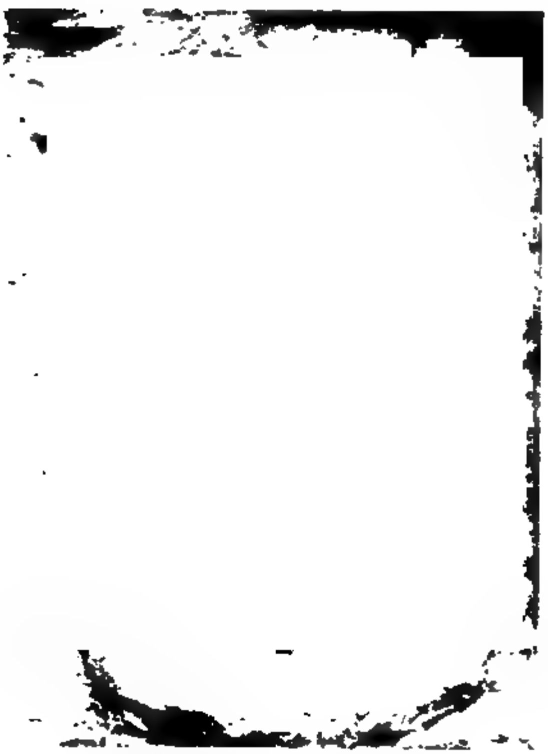
As fatigue becomes more profound, effort is centred in an endeavour to keep the eyes open, and the levator palpebræ superioris becomes weakened; the frontalis is put into action, giving the very characteristic and contradictory expression seen in this mask of advanced fatigue (fig. 4), which represents the runner in the last stage of exhaustion. The long doubly curved wrinkles across the forehead, with arched eyebrows, are usually associated with the expression of surprise and astonishment, but here they show the endeavour to raise the closing eyelid by this indirect means, since the proper muscle can no longer be made to act. The nostrils are dilated, and the lips drawn outward and downward by the platysma. This part of the face shows the distress of impeded respiration. The head is thrown backward and the chin thrust forward, as we see in all endeavours to balance the head upon the neck without muscular effort. This pose of the head is characteristic of fatigue. It is well shown in the "Sleeping Boy" by Van Dyck. Both pose and facial expression are characteristic of the last effort to fight off collapse, and are a warning of the near approach of complete breakdown.

When this last feeble effort is exhausted, the face gives mute expression to the final stage of fatigue, the muscles of expression cease to act, the countenance takes on a look of absolute apathy, the cheek hangs relaxed, and the gaping mouth completes the pathetic picture of helpless collapse.

Few runners can or will push their powers to this extreme limit of endurance.

No. 1.—Violent Effort

No. 2.—Breathlessness.



No. 3.—Fatigue.

No. 4.—Advanced Fatigue.

PROF. R. TAIT M'KENZIE.

A CASE OF ABSENCE OF THE CORPUS CALLOSUM. By D. DOUGLAS-CRAWFORD, M.B., F.R.C.S., *Lecturer on Surgical and Applied Anatomy in the University of Liverpool; Hon. Surgeon to the Liverpool Stanley Hospital.* (PLATE XV.)

THE rarity of such a condition is strongly emphasised by the few references found throughout the literature of the past century. Reil appears to have described the earliest case in 1812; and in 1888, when Bruce read a paper upon the subject before the Royal Society of Edinburgh (*Proceedings*, xv.), he was only able to give a list of 30 cases. I have been unable to find reports of any more recent cases.

Bruce arranges these 30 cases in four groups:—

(*a*) In 15 there was complete absence.
(*b*) In 6 there was partial development.
(*c*) In 3 the anterior portion was absent.
(*d*) In 6 the absence was obviously secondary to a tumour.

Upon reading the reports of these cases one is struck by the fact that most of them are descriptions of the brains of idiots or epileptics, and that other gross defects were found at the autopsy, such as abnormally distended ventricles; and Turner (*Journ. Anat. and Phys.*, xii., 1878) considered this condition of the ventricles as the main factor in arresting the callosal development (Knox's case—*Glas. Med. Journal*, 1875).

Only 5 of the 30 cases were brains of people of average intelligence. These were:—

(1) Malinverni's case (*Giornal del. R. Acad. di Torino*, 1874): A soldier, died at age of 40. Corpus callosum, septum lucidum, and gyrus fornicatus absent.

(2) Eichler's case (*Arch. f. Psychiatrie*, vol. viii. pt. ii., 1878): A sober, industrious labourer, father of a well-developed child; a good husband; could read and write. Died æt. 43 from gangrene of the scrotum.

(3) Paget's case (*Med. Chir. Trans.*, 1846): Female; mental condition fairly normal. Died æt. 21. C. callosum 1·4 inch long.

(4) Jolly's case (*Zeitschrift f. Rationelle Medicin*, Bd. xxxvi., 1869): Railway servant, mental power normal. Died æt. 58 from cancer of the stomach. C. callosum about 1 inch in length.

(5) Bruce's case (*Brain*, vol. xii., 1890): Male; had been a light porter in one firm for thirteen years. Died from pneumonia.

All 5 cases are included in Group (*a*) of Bruce's classification.

From these cases it is obvious that absence of this commissure is not incompatible with mental efficiency.

The specimen which has come under my notice was removed from an elderly male subject in the dissecting room. Unfortunately, I have been unable to trace the previous history.

The corpus callosum is represented by a round bundle of fibres, half an

External surface of right cerebral hemisphere.

inch in diameter, placed immediately anterior to the anterior pillar of the fornix and dorsal to a normal-sized anterior commissure.

Both hemispheres are richly convoluted, but there are certain irregularities in the arrangement of the sulci.

External Surface.—Frontal lobes. The superior and middle convolutions are subdivided by an accessory sulcus parallel to the pre-central. The pars basilaris of the right hemisphere is especially well developed. The pre-central sulcus has a more forward direction on the right than on the left hemisphere, culminating in a strongly-marked genu at the posterior end and superior border of the inferior frontal convolution. The ascending frontal convolution of the right side is narrow above and broad below, the reverse obtaining on the left hemisphere.

The left fissure of Rolando is forked superiorly, cutting off a portion of

the ascending frontal convolution, and ends fully an inch from the mesial border of the hemisphere.

Right Post-central Sulcus.—The inferior ramus intersects the posterior limb of the Sylvian fissure; the superior ramus is extremely short: the horizontal ramus curves backwards almost reaching a well-defined arcus parieto-occipitalis, but separated from it by a slender convolution continuous with the angular gyrus.

The right supra-marginal gyrus is well developed, and delimited by a shallow sagittally directed sulcus from the superior temporal gyrus.

External surface of left cerebral hemisphere.

The angular and posterior parietal gyri are very irregularly indented by shallow sulci.

Left Post-central Sulcus.—The superior ramus is longer than on the right side; the horizontal ramus curves backwards to become continuous with a sulcus on the occipital lobe parallel with the ramus occipitalis, and in this way is continued to the posterior margin of the brain; the left superior parietal convolution takes a serpentine course backwards to become continuous with the middle part of the occipital lobe.

The left supra-marginal lobe resembles the right, but the secondary sulci all radiate from a spot just behind the posterior limb of the Sylvian fissure. In this hemisphere we see a crowding out, as it were, of portion of the parietal lobe due to excessive development of the upper part of the ascending frontal and ascending parietal gyri

Temporal Lobes and Sulci.—The right first temporal sulcus is continued outwards and upwards over the outer surface of the hemisphere by sulci of varying depths, to end just short of the most convex portion of the ramus horizontalis.

The posterior part of the temporal and posterior parietal regions is subdivided by shallow sagittally disposed sulci, parallel to, indirectly continuous with, the first temporal sulcus.

The left first parallel sulcus takes a fairly straight course backwards, ending in a widely-forked extremity.

Mesial surface of left cerebral hemisphere.

Mesial Surface.—The right calloso-marginal sulcus begins on the same level, and just anterior to, the rudimentary corpus callosum: on the left, this sulcus begins well below the corpus callosum near the inferior margin of the hemisphere. They terminate just beyond the anterior end of the optic thalamus at a point corresponding to the pre-central sulcus.

The right marginal convolution is broad, and deeply indented by four radially directed sulci; the first passes below the commencement of the calloso-marginal sulcus, the other three pass from the margin of the hemisphere directly into the calloso-marginal sulcus.

The marginal lobe is limited behind by a deep triradiate sulcus, one limb of which passes around the upturned end of the callosal convolution to become continuous with the ventricle.

The anterior end of the callosal convolution is much broader on the left side than on the right.

The para-central and precuneate lobes of both hemispheres are well defined, and deeply indented by radially directed sulci continuous with the ventricular margin.

The right internal parieto-occipital fissure is cut off from union with the calcarine by the appearance on the surface of the cuneo-lingual gyrus, and in consequence the anterior limb of the calcarine fissure is completely separated from the posterior. Just at the point of separation the tip of the cuneate lobe is considerably raised above the surface.

Although variations in the convolutions and sulci exist throughout the whole of each hemisphere, the irregularities on the external surface are especially marked. (1) In the unusual subdivision of the superior and middle frontal convolutions, and the great difference in shape between the right and left ascending frontal convolutions. (2) In the left fissure of Rolando, the upper end of which is widely forked. (3) In the irregular indentation by shallow sulci of certain gyri, especially the angular and posterior parietal. It is to be noted that these sulci, especially on the left hemisphere, radiate from a point just behind the posterior limb of the Sylvian fissure. It has been pointed out by Cunningham that in all brains in which the corpus callosum is absent the sulci have a special tendency to radiate from the Sylvian fissure.

On the mesial surface are to be noted (1) the short gyrus fornicatus; (2) the complete separation of the anterior and posterior limbs of the calcarine fissure by the cuneo-lingual gyrus appearing on the surface; (3) the radiate arrangement of the sulci.

The left hemisphere was further examined (Pl. XV., C.). The callosal and marginal gyri were torn outwards, bringing into view (*a*) a narrow marginal band lying on the dorsal surface of the rudimentary corpus callosum, which could be traced forwards and downwards in front of the anterior commissure to become continuous with the olfactory tract; the dorsal portion was intimately associated with the fornix, and wound around the posterior end of the optic thalamus, where it presented a well-marked serrated eminence (the Balkenwindung of Retzius), diminishing in size as it passed onwards to the uncus, and finally becoming lost in the region of the lateral root of the olfactory tract. The relations and connections of this "marginal band" suggest a complete limbic lobe.

(*b*) The fornix, which showed a failure of union of the body with its fellow of the opposite side, and a considerable number of the fibres of the anterior pillar passed in front of the anterior commissure; these fibres (the pre-commissural fibres of Huxley) could be readily traced

into the precommissural area of Elliot Smith or gyrus subcallosus of Zuckerkandl.

(c) White fibres passing apparently from the different portions of the cortex to become lost in the limbic lobe.

Six coronal sections of the left hemisphere were now made, the first passing through the anterior portion of the rudimentary corpus callosum, the last through the posterior horn of the lateral ventricle.

The first shows that the fibres of the corpus callosum connect across the middle line only the anterior portions of the frontal lobes; the posterior portions and ascending frontal convolutions of opposite sides are apparently not thus associated, nor do any fibres pass downwards into the orbital portions of these lobes (Pl. XV. fig. 1).

The second shows the anterior commissure dissected out; its connections were apparently normal (Pl. XV. fig. 2).

The third shows a bundle of longitudinally directed white fibres placed dorsal to the descending horn of the lateral ventricle. I venture to suggest that these are some of the fibres of the inferior longitudinal fasciculus (Pl. XV. fig. 3).

The fourth and fifth do not present any special features; but in the sixth the posterior cornu is almost surrounded by a narrow but very distinct band of white fibres, which appear to take origin from the limbic lobe. They suggest a well-developed tapetum, but I hardly dare state dogmatically that they are tapetum fibres in the face of the researches of Ferrier and Turner.

These sections do not suggest any marked increase in size in the ventricles: the posterior horn may be slightly larger than usual.

In describing this case, I have used the terms "commissure bed" and "pre-commissural area" in the same sense as they are employed by Elliot Smith in his paper on the morphology of the limbic lobe. His "commissure bed" is that portion of the lamina terminalis lying dorsally to the anterior commissure, the "pre-commissural area" being the most anterior portion of the pars intermedia of the primitive limbic lobe.

The case appears to support Elliot Smith's views of the development of this great commissure rather than the older "fusion theory" which His, Mihalkovicz, and others support.

While it is useless to speculate upon the possible mental condition of the man from whom this brain was removed, yet it is of interest to note how closely it resembles in many respects the brains included in Bruce's first group, in five of which there was mental efficiency.

The specimen demonstrates that the fornix commissure appears before the callosal, and that the dorsal portion of the corpus callosum is the first

part of that commissure to appear in the commissure bed immediately anterior to the fornix.

My thanks are due to Dr Gordon Thompson (University Gee Fellow) for the very careful and accurate drawings of the different sections.

DIAGRAMS.

Figures 1 to 5 indicate sections made through the left hemisphere at the points indicated upon fig. C.

a.c. anterior cornu lateral ventricle.
c.n. caudate nucleus.
l.l. limbic lobe.
c.c. corpus callosum.
c.s. corpus striatum.
i.c. internal capsule.
s.f. Sylvian fissure.
o.t. optic tract.
a.com. anterior commissure.
f. fornix.
p. putamen.
e.c. external capsule.
cl. claustrum.
b. bundle of longitudinal fibres.
d.c. descending cornu of lat. ventricle.
gl.p. globus pallidus.
c.a. corpus albicans
o.th. optic thalamus.
str.m. striæ medullares.
a.n. amygdaloid nucleus.
x. junction of posterior and descending horns of lat. ventricle.
B.w. Balkenwindung.
c.m.f. calloso-marginal fissure.
p.c.a. pre-commissural area.
cr. crus cerebri.
f.m. foramen of Monro.
m.c. middle commissure.
v.d.a. bundle of Vicq d'Azyr.
c.b commissure bed.
p.v. perforating blood vessel.
a.p.s. anterior perforated spot.
ol.t. olfactory tract.

A.

f. fornix.
c.m.f. calloso-marginal fissure.
c.c. rudimentary corpus callosum.
p.c.a. pre-commissural area.
o.t. optic tract.
a.com. anterior commissure.
c.a. corpus albicans.
c.r. crus cerebri.
o.th. optic thalamus.
f.m. foramen of Monro.

B.

m.c. middle commissure.
v.d.a. bundle of Vicq d'Azyr.
p.c.a pre-commissural area.
c.b. commissure bed.

C.

p.v. perforating blood vessel.
B.w. Balkenwindung.
a.p.s. anterior perforated spot.
ol.t. olfactory tract.
l.l. limbic lobe.
f. fornix.

s.c.

f. f.m.

o.th. l.l. c.n.

c.m.f. c.c.

c.c.

FIG. 1.

A. p.c.a. o.t. a.com. c.a. c.r.

m.c.

f

a.com

v.d.a.

c.

B.

FIG. 2.

p.v.

l.l.

p.

c.n. s.c.

f.

str.m. d.

o.th.

i.c.

c.a. b.

gl.p.

d.c.

C.

FIG. 3.

B.w. f. a.p.s. ol.t. l.l

c.n.

l.l.

f.

a.n.

B.

FIG. 5. FIG 4.

MR D. DOUGLAS-CRAWFORD.

THE CIRCLE OF WILLIS: AN EXAMINATION OF 700 SPECIMENS.

By Professor E. FAWCETT, *University College, Bristol*, and Dr J. V. BLACHFORD, *Medical Superintendent, City and County Asylum, Bristol.*

THIS investigation is another of the series of which we have from time to time published reports. The only other we know of on the same subject—that of Dr Windle—was published in the year 1888 in this Journal, and dealt with 200 specimens. Our results are derived from an analysis of more than three times that number of cases, and, taken along with these, should furnish statistics which may be considered as affording reliable averages.

PLAN OF REPORT.

We first examined the circle with a view to finding how often it was complete, how often incomplete. When incomplete, we ascertained to what the non-completion was due.

Then we inquired into the symmetry or asymmetry, and, when asymmetry was found, determined its nature and the frequency with which it occurred. Having done this, we made and recorded observations on most of the arteries entering into the circle. The question of the influence of sex was considered, and is reported on.

THE CIRCLE OF WILLIS COMPLETE.

In 700 specimens we found the circle complete 673 times, or 96·1 per cent.

In 350 females it was complete 334 times, or 95·4 per cent.

In 350 males it was complete 339 times, or 96·8 per cent.

$$\left.\begin{array}{l}\text{F. } 334\\ \text{M. } 339\end{array}\right\} 350 \left\langle \begin{array}{l} 95{\cdot}4 \text{ per cent.}\\ 96{\cdot}8 \quad ,, \end{array}\right\} \text{ Total } \frac{673}{700} = 96{\cdot}1 \text{ per cent.}$$

THE CIRCLE OF WILLIS INCOMPLETE.

It was incomplete in 27 cases, or 3·8 per cent.

In 350 females it was incomplete 16 times, or 4·5 per cent., and in a similar number of males 11 times, or 3·1 per cent.

$$\left.\begin{array}{l} \text{F. } \frac{16}{350} = 4{\cdot}5 \text{ per cent.} \\ \text{M. } \frac{11}{350} = 3{\cdot}1 \quad \text{,,} \end{array}\right\} \text{Total } \frac{27}{700} = 3{\cdot}8 \text{ per cent.}$$

Nature of Incompleteness.

This was due to:—

a. Absence of one or both posterior communicating arteries.
b. Absence of the anterior communicating artery.

a. Absence of one or both Posterior Communicating Arteries is not a common condition according to our tables, not nearly so common as Windle reports. When one artery is absent, it is more commonly the right one.

(a_1) Absence of one Posterior Communicating Artery: The Right.

The right posterior communicating artery was absent 13 times—1·8 per cent.; in 350 females it was absent 5 times, or 1·4 per cent., and in 350 males it was absent 8 times, or 2·2 per cent.

$$\left.\begin{array}{l} \text{F. } \frac{5}{350} = 1{\cdot}4 \text{ per cent.} \\ \text{M. } \frac{8}{350} = 2{\cdot}2 \quad \text{,,} \end{array}\right\} \text{Total } \frac{13}{700} = 1{\cdot}8 \text{ per cent.}$$

Windle's figures, quoted in Quain's *Anatomy*, show absence of this artery in 4·5 per cent of cases.

(a_2) The Left.

This artery is not so commonly absent as the right one, being absent only 10 times, as against 13, in 700 cases, or 1·4 per cent. It was, unlike the right one. more commonly absent in females. Thus, in 350 females it was absent 7 times, and in a corresponding number of males 3 times. It was therefore more than twice as often absent in females as in males.

$$\left.\begin{array}{l} \text{F. } \frac{7}{350} = 2 \text{ per cent.} \\ \text{M. } \frac{3}{350} = {\cdot}85 \quad \text{,,} \end{array}\right\} \text{Total } \frac{10}{700} = 1{\cdot}4 \text{ per cent.}$$

According to Windle, it is absent in 6·5 per cent. of cases.

(a_3) Absence of both Posterior Communicating Arteries.

This is a very uncommon condition, occurring in our specimens but 3 times—each time in a female—·4 per cent. Windle found it as often as 1·5 per cent.

It is a little difficult to account for these wide differences between our results and those of Windle. Can there be a difference in the insane, or is it due to the great difference in the number examined?

b. Absence of the Anterior Communicating Artery.

This must be a very rare condition as we met with it only once, and that in a female. Windle notes several cases of absence of the anterior communicating artery, mostly due to fusion of the anterior cerebrals.

SYMMETRY OF THE CIRCLE OF WILLIS.

The circle was symmetrical in 514 cases out of 700, or in 73·4 per cent.

In 350 females it was symmetrical 248 times, and in a corresponding number of males 266 times.

$$\left.\begin{array}{l} \text{F. } \dfrac{248}{350} = 70{\cdot}8 \text{ per cent.} \\ \text{M. } \dfrac{266}{350} = 76 \quad\quad ,, \end{array}\right\} \text{Total } \frac{514}{700} = 73{\cdot}4 \text{ per cent.}$$

It was complete and symmetrical 510 times out of 700, or 72·8 per cent.—244 times in the female, or 66·7, and 266 times in the male out of 350 cases, or 76 per cent.

$$\left.\begin{array}{l} \text{F. } \dfrac{244}{350} = 66{\cdot}7 \text{ per cent.} \\ \text{M. } \dfrac{266}{350} = 76 \quad\quad ,, \end{array}\right\} \text{Total } \frac{510}{708} = 72{\cdot}8 \text{ per cent.}$$

ASYMMETRY OF THE CIRCLE OF WILLIS.

This has many causes, thus:—

a. Variation in size between the two posterior communicating arteries.
b. Absence of an artery in the circle.
c. Doubling of one anterior cerebral artery.
d. Abnormal origin of the posterior cerebral arteries.

a. Variation in Size between the two Posterior Communicating Arteries.

(a_1) *The Right Posterior Communicating Artery was larger than the left* in 87 cases out of 700, or 12·4 per cent. In 350 females, 45 times, or 12·8; in males, 42 times, or 12 per cent.

$$\left.\begin{array}{l} \text{F. } \frac{45}{350} = 12{\cdot}8 \text{ per cent.} \\ \text{M. } \frac{42}{350} = 12 \quad \text{,,} \end{array}\right\} \text{Total } \frac{87}{700} = 12{\cdot}4 \text{ per cent.}$$

(a_2) *The Left Posterior Communicating Artery was larger than the right* in 64 cases out of 700, or 9·1 per cent. In 350 females, it was the case 37 times, or 10·5 per cent.; and in 350 males, 27 showed this condition, or 7·7 per cent.

$$\left.\begin{array}{l} \text{F. } \frac{37}{350} = 10{\cdot}5 \text{ per cent.} \\ \text{M. } \frac{27}{350} = \ 7{\cdot}7 \quad \text{,,} \end{array}\right\} \text{Total } \frac{64}{700} = 9{\cdot}1 \text{ per cent.}$$

It is evident that the right artery is more often, by its enlargement, the cause of asymmetry than the left one, thus $\frac{\text{R. } 87}{\text{L. } 64} = \frac{12{\cdot}1}{9{\cdot}1}$ per cent.

This tallies with Windle's observation.

b. Absence of an Artery in the Circle.

So far as our observations go, it is the posterior communicating alone which is concerned here.

(b_1) *The Right Posterior Communicating was absent* 13 times out of 700, or 1·8 per cent, and it was more often absent in males than females, thus:—

$$\left.\begin{array}{l} \text{F. } \frac{5}{350} \\ \text{M. } \frac{8}{350} \end{array}\right\} \text{Total } \frac{13}{700} = 1{\cdot}8 \text{ per cent.}$$

(b_2) *The Left Posterior Communicating Artery was absent* 10 times in 700, or 1·4 per cent. It was twice as often absent in females as in males, thus:—

$$\left.\begin{array}{l} \text{F. } \frac{7}{350} \\ \text{M. } \frac{3}{350} \end{array}\right\} \text{Total } \frac{10}{700} = 1{\cdot}4 \text{ per cent.}$$

c. Doubling of one Anterior Cerebral Artery.

This is a rare cause of asymmetry, occurring only twice, or ·28 per cent., once in a male and once in a female.

In the *male* it divided into two within the circle, and when without the two united.

In the *female* the two reunited within the circle. In both cases it was the right artery which was affected.

d. Asymmetry due to Abnormal Origin of the Posterior Cerebral Arteries.

(d_1) *The Right Posterior Cerebral* in 6 cases out of 700 arose from the corresponding internal carotid, four times in females, twice in males, thus:—

$$\left.\begin{array}{l} \text{F. } \frac{4}{350} = 1{\cdot}1 \text{ per cent.} \\ \text{M. } \frac{2}{350} = \ {\cdot}57 \quad \text{,,} \end{array}\right\} \text{Total } \frac{6}{700} = {\cdot}85 \text{ per cent.}$$

(d_2) *The Left Posterior Cerebral Artery* arose in 4 cases out of 700 from the corresponding internal carotid, or ·57 per cent., three times in females and once in males, thus:—

$$\left.\begin{array}{l} \text{F. } \frac{3}{350} = {\cdot}7 \text{ per cent.} \\ \text{M. } \frac{1}{350} = {\cdot}28 \quad \text{,,} \end{array}\right\} \text{Total } \frac{4}{700} = {\cdot}57 \text{ per cent.}$$

Asymmetry due to abnormal origin of the posterior cerebral arteries is evidently twice as common in the female as the male.

Female : Male : : 7 : 3

Observations on some of the Arteries entering into the Circle of Willis.

The Anterior Communicating Artery.

This was only absent once, and that in a female. It was found to be single or double, or even treble, and it might be I-shaped.

It was *single* in 645 out of 700, or 92·1 per cent.; in 350 females it was single 315 times, or 90 per cent., and in the same number of males 330 times, or 97·1 per cent.

$$\left.\begin{array}{l} \text{F. } \frac{315}{350} = 90 \text{ per cent.} \\ \text{M. } \frac{330}{350} = 97{\cdot}1 \quad ,, \end{array}\right\} \text{Total } \frac{645}{700} = 92{\cdot}1 \text{ per cent.}$$

The artery was *double* in 51 cases out of 700, or 7·2 per cent.; was 32 times double in females, or 9·14 per cent., and 19 times double in males:—

$$\left.\begin{array}{l} \text{F. } \frac{32}{350} = 9{\cdot}14 \text{ per cent.} \\ \text{M. } \frac{19}{350} = 5{\cdot}7 \quad ,, \end{array}\right\} \text{Total } \frac{51}{700} = 7{\cdot}2 \text{ per cent.}$$

The artery was *treble* in one case only, and that case was a male. It occurred in a case in which a third anterior cerebral artery was present.

The artery was **I**-*shaped* (like the letter **H** laid horizontally). This was met with twice, both being in females.

The Third Anterior Cerebral Artery.

This artery arises as a rule from the anterior communicating artery.

It was present 23 times in 700, or 3·2 per cent.—Windle says 4·5 per cent. It seems to be much more common in the male than the female, for it was met with 19 times in 350 males, or 5·7 per cent., and only 4 times in the females, or 1·1 per cent.

$$\left.\begin{array}{l} \text{F. } \frac{4}{350} = 1.1 \text{ per cent.} \\ \text{M. } \frac{19}{350} = 5{\cdot}7 \quad ,, \end{array}\right\} \text{Total } \frac{23}{700} = 3{\cdot}2 \text{ per cent.}$$

In one case, a male, the artery arose by two roots, one from each anterior cerebral. In two cases it arose directly from the left anterior cerebral artery, one in a male, the other in a female.

In another case, in which there were three anterior communicating arteries present, it arose from the middle one.

Nothing need further be said about the other arteries entering into the circle—they have already been fully dealt with; but it may be interesting to note that in two females the basilar artery, after giving off two posterior cerebrals, bifurcated into two posterior communicating arteries.

We may now sum up:—

The circle is usually complete and symmetrical. If incomplete, that is due to absence of one or both posterior communicating arteries, or of the

anterior communicating—a very rare condition. Absence of the posterior communicating arteries is not so common as stated.

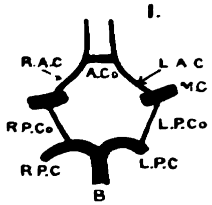
If asymmetrical, it may be due to absence of a posterior communicating artery, to doubling of an anterior cerebral artery, or abnormal origin of one posterior cerebral.

The anterior communicating artery is more often double in females than in males.

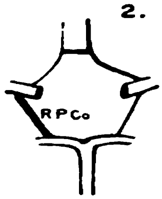
A third anterior cerebral artery is much more often present in males than in females.

CIRCLE OF WILLIS.

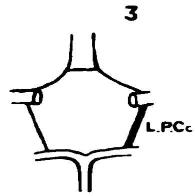
	Total.	Percentage.	Females.	Percentage.	Males.	Percentage.
Complete	673	96·1	334	95·4	339	96·8
Incomplete	27	3·8	16	4·5	11	3·1
Symmetrical	514	73·4	248	70·8	266	76
Asymmetrical	186	26·5	102	29·1	84	21·1
Complete and symmetrical	510	72·8	244	66·7	266	76
R. post. com. > left	87	12·4	45	12·8	42	12
L. ,, ,, > right	64	9·1	37	10·5	27	7·7
R. ,, ,, absent	13	1·8	5	1·4	8	2·2
L. ,, ,, ,,	10	1·4	7	2	3	·85
Both absent	3	·4	3	·85	0	0
Both very small	5	·7	3	·85	2	·57
Ant. communicating absent	1	·14	1	·28	0	0
,, ,, single	645	92·1	315	90	330	94·2
,, ,, double	51	7·2	32	9·1	19	5·7
,, ,, treble	1	·14	0	0	1	·28
,, ,, I-shaped	2	·28	2	·57	0	0
R. P. cereb. from int. car.	6	·85	4	1·1	2	·57
L. P. ,, ,,	4	·57	3	·7	1	·28
Both ,, ,,	1	·14	1	·28	0	0
3rd ant. cerebral	23	3·2	4	1·1	19	5·7
	700 Total.		350 Females.		350 Males.	



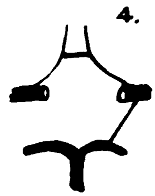
1. Complete and symmetrical, 72·8 per cent.



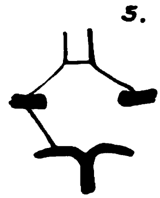
2. Right post. communicating larger than left. 12·4 per cent.



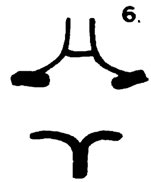
3. Left post. communicating larger than right, 9·1 per cent.



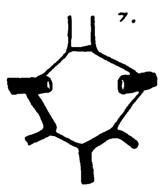
4. Right post. communicating absent, 1·8 per cent.



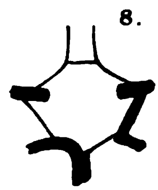
5. Left post. communicating absent, 1·4 per cent.



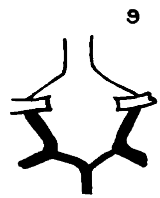
6. Both post. communicating arteries absent, ·4 per cent.



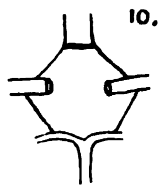
7. Right post. cereb. from int. carotid, ·85 per cent.



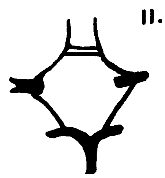
8. Left post. cereb. from int. carotid, ·57 per cent.



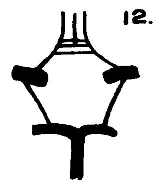
9. Both post. cerebrals from int. carotids, ·14 per cent.



10. Ant. communicating single, 92·1 per cent.



11. Ant. communicatingdouble, 7·2 per cent.



12. Ant. communicating treble, ·14 per cent.

FIG. 1.

B.—Basilar artery.
R.P.C.—Right post. cerebral artery.
L.P.C.—Left post. cerebral artery.
R.P.Co.—Right post. communicating.
L.P.Co.—Left post. communicating.
M.C.—Middle cerebral artery.
L.A.C.—Left anterior cerebral.
R.A.C.—Right anterior cerebral.
A.Co.—Anterior communicating.

AN ACARDIAC FŒTUS (*Acephalus omphalositicus*). By Reginald J. Gladstone, M.D., F.R.C.S., *Middlesex Hospital, London, W.* (Plates XVI.–XVIII.)

Although the external characters of a number of acardiac fœtuses of different kinds have been described (1–5), comparatively few records have been published in which there is a clear and complete account of the internal anatomy of these rare monsters. Moreover, the course of the circulation, and the means by which the blood is propelled through the fœtus and placenta, are of such interest that no apology is needed for giving a detailed description of the following specimen.

These monsters are always associated with a twin fœtus, whose heart carries on the circulation in both, there being a direct anastomosis between the vessels in the placenta of the normal fœtus or *autosite*, and the umbilical vessels of the acardiac fœtus or *omphalosite*. An acardiac fœtus is obviously incapable of separate existence after birth; and even while *in utero* its life is maintained not only by the mother, but it is also dependent on the twin fœtus with which it is associated. The omphalosite is dependent on the mother for nutritive material and for the arterialisation of its blood, which takes place in the placenta, while it is dependent on the autosite for the motive power by which the circulation of blood through it is accomplished.

The specimen (fig. 3) which forms the subject of this paper was sent by Dr M. Grabham from the Jubilee Lying-in Hospital, Kingston, Jamaica, to Dr Robert Boxall; and I have to express my thanks to Dr Boxall for permission to dissect the specimen, and to Dr Grabham for the following particulars with regard to its birth. The specimen was one of three male fœtuses which were born together at full term. Two of these were undersized, but otherwise normal in appearance; these were born first, the head presenting, the acardiac fœtus being born shortly afterwards, and with a "breech presentation." There was no excess of liquor amnii, and there was no history of any congenital malformation having occurred in children which had been born previously.

Placenta and Membranes.

The "after-birth" (figs. 1 and 2) appeared at first sight to be a specimen of *triple placenta*, for there were three separate amniotic sacs and three

umbilical cords. The placenta, with the membranes and cords attached, weighed 305 grm. (10·7 oz.), and measured in its longest transverse diameter 16 cm. (6¼ in.). One amniotic sac smaller than the other two was presumably the sac which contained the acephalic monster. The length of each of the umbilical cords belonging to the two larger sacs was 25 cm. (9¾ in.), that of the smaller 16·5 cm. (6½ in.). The thickness of the latter was also much less than that of the other two, and on making a transverse section through it, only two vessels could be recognised—namely, the umbilical vein and one umbilical artery. The vessels of the two larger cords were normal in number and appearance. Each amniotic sac was independent; for where two amniotic sacs were in contact with one another, although the partition separating them appeared to be a single membrane, it was found possible, by gentle traction, to completely separate the two layers of which it was composed, and to afterwards strip each membrane off the amniotic surface of the placenta as far as the point of insertion of the corresponding umbilical cord. There was, however, no intervening tissue visible between any two of the amniotic sacs—a circumstance which is in favour of the view that there were three germinal areas or "inner cell-masses" developed within a single ovum (6).

On examining the uterine surface of the placenta, it was seen that the cotyledons were arranged in an annular manner round the periphery of the organ, and that, though they were in contact with one another in the centre, so that the placenta appeared to be disc-shaped, there was no vascular communication between the cotyledons of opposite sides.

On following the distribution of the vessels, it was found that one of the umbilical arteries, and a main branch of the umbilical vein belonging to the cord marked *Au.* in fig. 2, were directly continuous with the umbilical artery and umbilical vein of the smaller cord, *Om.*, belonging to the acardiac fœtus or omphalosite. The umbilical vessels of the acardiac fœtus had therefore no connection with the cotyledons of the placenta; moreover, the part of the placenta into which the cord of the omphalosite appeared to be inserted belonged really to the autosite. Thus, strictly speaking, the omphalosite had no placenta; for its umbilical vessels, after the cord had joined the placenta, merely ran for a distance of between 2 and 3 inches beneath the amnion to the point of insertion of the autosite's cord, where they became directly continuous with its vessels, without having given off any branches to the neighbouring cotyledons.

External Characters of the Fœtus.

The acardiac fœtus (fig. 3) weighed 285 grm. (10 oz.), and measured, when the legs were extended, 20 cm. (8 in.). It was of the male sex, and its

most noticeable feature was the complete absence of the head and neck; the trunk being expanded above into a rounded mass consisting of a covering of skin, which was afterwards found to enclose a very considerable thickness of pale, œdematous connective tissue. The skin generally was much creased and wrinkled, this condition being due to shrinkage following the escape of œdematous fluid, which had formerly occupied the spaces in the subcutaneous tissue.

Through the umbilical opening there protruded some coils of small intestine, the cæcum and appendix, and a small portion of the ascending colon.

About 1 cm. above the level of the umbilicus were two symmetrically placed hemispherical rounded swellings, 3 cm. in diameter, and characterised by a central depression, where the skin was deeply pigmented; these proved to be the two breasts.

In the middle line, 3 cm. above the umbilicus, and above and between the two mammary glands, was a rudimentary right upper extremity, consisting of an ovoid protrusion of the skin, which presented in its upper part one well-developed digit, on which a nail could be recognised, with the rudiments of two other fingers placed on each side of it. Above and to the left of the left breast was the rudimentary left upper extremity, bearing two digits, one of which was of large size, and showed a well-developed nail; this appeared to be the thumb: internally was a smaller digit, apparently the index finger, while two notches in the skin internal to this probably indicated the positions of the three remaining digits. The legs were crossed, and doubled up underneath the thighs, while the feet were in the position of pronounced talipes varus. The three outer toes of each foot were absent.

The external genitals were well formed and appeared normal. The anal depression, however, which was 2 mm. in depth, ended blindly, and it was found afterwards to be separated by about 3 mm. from the blind extremity of the rectum.

Appearances noted on Opening the Abdomen.

On opening the abdomen (fig. 4), the single umbilical artery was seen to pass downwards from the navel to the right of the urachus, and it was found afterwards that it joined the right internal iliac artery. A slight fold of peritoneum on the left of the urachus indicated the position of an obliterated left hypogastric artery. The umbilical vein ran vertically upwards in a fold of peritoneum on the posterior aspect of the anterior abdominal wall towards the upper part of the abdominal cavity.

All those viscera which are normally developed in connection with the upper part of the alimentary canal—namely, the respiratory organs, the thyroid and thymus glands, the liver, gall-bladder, pancreas and spleen, and the upper portion of the tube itself, including the pharynx, œsophagus, stomach, and duodenum—were absent. The small intestine commenced outside the abdomen in a blind extremity; on tracing the gut downwards, a small Meckel's diverticulum was found about an inch and a quarter from the ileo-cæcal junction. Further downwards but still outside the abdominal cavity, were the cæcum and appendix vermiformis, with the commencement of the large intestine, the whole being connected with the posterior abdominal wall by means of a common mesentery. The part of the large intestine within the abdominal cavity formed an ∽-shaped bend, which ended blindly in the lower and back part of the pelvis, in the usual position of the rectum. The rectum was completely separated from the bladder, and was about 3 mm. distant from the bottom of the anal depression. The whole of the intra-abdominal portion of the large intestine was filled with meconium, and lay on the left side of the abdomen, in front of the left kidney and suprarenal capsule.

The two kidneys and suprarenal capsules were well developed, the right, however, being the larger, and lying in direct contact with the anterior abdominal wall; whereas the left lay further back, and was concealed by the ∽-shaped bend of the large intestine. The two suprarenal bodies were in contact with one another by their mesial borders, and at first sight appeared to be a single organ. A little dissection, however, was sufficient to separate them completely, there being no fusion whatever of the gland-substance. The ureters appeared normal. The testicles, which were situated at the internal abdominal rings, and the vas deferens on each side appeared to be quite normal also.

Vascular System.

A single main artery, the abdominal aorta, was situated in the usual position, in front of the lumbar vertebræ (fig. 4); it bifurcated below into right and left common iliac arteries, each of which divided into an external and internal iliac branch. The right internal iliac artery *received* the right hypogastric artery, which conveyed the blood coming to the fœtus from the autosite, by means of the single umbilical artery described in connection with the placenta.

The aorta gave off lumbar, middle sacral, mesenteric, spermatic, and renal arteries, and was continued upward slightly to the left of the middle line,

into the areolar connective tissue lying above the cœlomic cavity; here it bifurcated into two main vessels, the branches of which appeared to anastomose with tributaries of the vena cava and of the umbilical vein.

The external and internal iliac veins on each side united to form a longitudinal trunk, which ran upwards to the kidney of the corresponding side. After having received the renal vein, the trunks joined to form a single vessel, which was continued upwards in front of the vertebral column parallel with and to the right of the aorta. This vessel, after having received a large tributary on the right, bifurcated in the upper part of the thorax into right and left branches, corresponding to the terminal divisions of the aorta.

The umbilical vein, or a large branch of it, passed upwards from the umbilicus on the posterior aspect of the anterior abdominal and thoracic walls, where it broke up into small terminal branches, which apparently anastomosed with the terminal branches of the aorta. I am unable to state the course which was taken by the mesenteric veins, as I unfortunately removed the mesentery with the intestines at an early stage of the dissection; a cut branch, however, which joined the right venous trunk just before its union with the corresponding vein of the left side probably represented their termination in that vessel, as a single trunk. This vessel would have corresponded in position to the normal "vena portæ" and the termination of the hepatic veins in the inferior vena cava.

Course of the Circulation.

The circulation of blood through the autosite and parasite would thus have had the following course:—Starting from the autosite's heart, it would have been propelled by this through the body of the fœtus, and would have ultimately left it by the umbilical arteries, and thus reached the placenta; part of this blood would have passed to the cotyledons of the placenta, and part by the anastomosing placental artery directly into the single umbilical artery of the smaller cord belonging to the omphalosite (fig. 2); by the continuation of this vessel within the body of the fœtus, viz. the right hypogastric artery (fig. 4), it would have reached the arterial system of the omphalosite, and have thus been distributed to its organs and tissues; from these it would have been returned to the placenta by the umbilical vein; here, close to the point of attachment of the autosite's cord, it would have been joined by the arterialised blood returning from that portion of the placenta which belonged to the autosite; and the mixed arterial and venous blood would then have been carried back by the umbilical vein to the autosite's heart, from whence it started.

The direction of the blood-current through the aorta and umbilical vessels of the acardiac fœtus would thus have been the reverse of that which is present in a normal fœtus; moreover, the blood supplied to the acardiac fœtus would have first passed through the body of the autosite, and thus be venous in character; and furthermore, the venous blood which left the omphalosite by its umbilical vein would have mingled with the arterial blood returning from the placenta to the autosite. One heart, therefore, pumped the blood through two fœtuses and one placenta; and one placenta sufficed as agent for the arterialisation of the blood and the nutrition of two fœtuses.

Nervous System.

The brain and the cervical portion of the spinal cord, with the corresponding cranial and cervical nerves, were completely absent; and it is noteworthy that the principal structures which are normally supplied by these nerves—namely, the diaphragm, the heart, and respiratory organs; the upper portion of the alimentary canal, along with the liver, pancreas, and spleen; the sense organs and structures connected with them—were also absent. The spinal cord and membranes ended abruptly at the level of the first dorsal vertebra, where the thecal tube appeared to open out directly into the œdematous connective tissue occupying the position of the head and neck. Below this point the cord and membranes, with the corresponding nerve roots, appeared normal. The sympathetic nerves in the lower portion of the thorax and in the abdomen also appeared normal.

The Skeleton.

The skull, the hyoid bone, and the cervical vertebræ were completely absent (fig. 5). The spinal column below had the normal number of segments, but there was marked kyphosis in the upper region of the thorax. Of the twenty presacral vertebræ which were present, the twelve upper bore ribs; the first ribs were, however, rudimentary, and are not visible in the skiagram.

All the thoracic and lumbar, and the three upper sacral vertebræ, showed the normal primary centres of ossification.

The sternum was represented by an irregularly shaped plate of cartilage connecting the costal cartilages of the four upper ribs.

The shoulder girdle on the right side was very rudimentary, consisting simply of a plate of bone surmounted by a dorsal strip of cartilage, which represented the scapula and supra-scapular cartilage, and a fibrous band connecting this with the upper end of the sternum. On the left side the

scapula was more fully developed, and showed a ventral notch, separating the acromion process from the head and coracoid process. A small ossified nodule, representing the clavicle, was also present. Beyond was an ossified humerus, about 4 mm. in length, articulating with a well-developed ulna 25 mm., or nearly an inch, in length; this was directed horizontally outwards, and is well seen in the skiagram (fig. 5); there was no radius, but the carpus and metacarpus appeared normal. The pelvic girdle and bones of the lower extremity, with the exception of the metatarsals and phalanges of the three outer toes of each foot, which were absent, appeared normal. Ossification of the shafts of the first and second metatarsals was well established, and it had commenced in the shafts of the corresponding digits.

Conclusions.

Apart from the question of etiology, the interest of this and similar cases centres to a large extent in the light that they may shed upon the early stages of development, and more especially on the development of the larger arteries and veins.

Although considerable variations as regards detail are present in those cases of acardiac fœtuses which have hitherto been recorded, there is a general similarity in their principal characters; thus:—

1. An acardiac fœtus is always associated with a twin fœtus, whose heart carries on the circulation in both.
2. One placenta usually, if not always, serves for both autosite and omphalosite.
3. The blood-current through the main vessels of the omphalosite is reversed.
4. The blood passing to the omphalosite passes directly to it from the autosite without previously traversing the capillary system of the placenta, and is therefore venous in character.
5. The blood passing to the autosite through its umbilical vein is a mixture of the venous blood returning from the omphalosite with arterial blood returning from the placenta.
6. The tissues of the acardiac fœtus are usually œdematous.

Etiology.

The existing theories regarding the causation of omphalositic monsters apparently require considerable modification in order to bring them into harmony with modern views. According to Ahlfeld: "Two healthy embryos develop on a single 'yolk'; the allantois of one is formed a few

hours sooner than that of the other; the allantois of the former reaches the internal surface of the primary chorion, and grows entirely or partly around it; the allantois of the latter now endeavours to reach the same destination. If the first has spread all over the inner surface of the chorion, the second can establish no direct connection with the chorion, but must be inserted in the first formed allantois; if, however, a small area of the chorion remains free, the second allantois can establish a connection with this part, whether it corresponds with the decidua vera or reflexa. When the connection is formed with the decidua reflexa, the second embryo does not acquire a distinct placenta, but must utilise the allantois of the first for the insertion of its vessels; but in the former case, when the small portion of unoccupied chorion corresponds with the decidua vera, the second embryo gains a small portion of the common placenta for the insertion of its vessels. Dependent on this difference of arrangement in early embryonic life, Ahlfeld classifies the omphalosites into 'true' or 'pure' and 'secondary allantoic parasites.'. . . In consequence of the inosculation of the umbilical vessels of the omphalosite with the large umbilical and placental vessels of the autosite, the two blood-currents meet in opposing streams. The heart-power of the first embryo or autosite being the greater, the blood-current of the second is reversed, flowing back through the umbilical artery to the trunk and heart, passing through the latter as though it were a simple continuation of the blood-channel. Consequently the heart atrophies or finally disappears, becoming simply a passive part of the blood-vessels which are continuous with it. Following the failure of cardiac development, there is absence or imperfect development of other internal organs and of important regions of the body, as the head and upper extremities." [1]

Ahlfeld thus regards the defect in development of the upper portion of the body in acardiac fœtuses as secondary to a failure in the development of the heart.

Breus, however, in 1882, contended that "the acardiaci, on account of an early disturbance of their embryonic development, are such highly defective products of conception that they are not capable of an independent circulation or of an intra-uterine nutrition; but they nevertheless continue to develop and to grow, because a supplementary circulation maintains their tissues in a living and growing state. They are usually found in twin ova along with a normal fœtus, for under these circumstances, by anastomosis of the umbilical vessels of both fœtuses, the vicarious circulation is most easily established."

According to Breus, therefore, the omphalosite dies, and no longer pos-

[1] Quoted from account in Hirst and Piersol's *Human Monstrosities*, p. 129.

sesses an independent circulation. Then the blood-current of the autosite enters the vessels of the omphalosite, and keeps it nourished to an imperfect degree.

The balance of evidence appears to be in favour of the latter view—namely, that the defective development of the head and upper extremities is probably primary, or at any rate is not secondary to a failure in the development of the heart; and further, that this failure in the development of the heart itself is also a primary condition, and not due to a reversal of the blood-current in one twin by a more powerful circulation in the other. If the failure in the development of the head and upper limbs were merely caused by failure in the circulation, dating from the time that the blood-current in the omphalosite was reversed, as it was supposed, by the stronger fœtus, the form of the undeveloped portions of the acardiac fœtus would, presumably, be that of a normal fœtus of a corresponding age, slightly modified by the growth of neighbouring parts, which is certainly not the case. Moreover, as Breus himself pointed out, acardiac fœtuses would be very much more common than they are, if their production was dependent upon the reversal of a weak blood-current by a stronger; for in all unioval twins anatomoses between the vessels of the two cords are invariably demonstrable, and one fœtus is usually better developed than the other. Moreover, the first portion of Ahlfeld's theory, viz. "the implantation of a second allantois within the first," does not coincide with modern views of the formation of the placenta. A more probable explanation is that two germinal areas or "inner cell-masses" are formed in a single ovum, each of which, after the formation of the mesoderm, has its separate "allantoic" or "belly" stalk. The growth of one embryo may be defective from the very first, or possibly the development of one embryo may mechanically interfere with proper development of the other. The extreme variation in form of omphalositic monsters, however (in some of which the head only is developed, while in others merely the lower extremities), indicates that the causes of the defects are to be sought for at a very early stage in development, and that the defects themselves are primary rather than secondary in nature.

In the specimen described in this paper, the anatomosis which apparently existed between the branches of the umbilical vein, with the two terminal branches of the aorta, is highly suggestive of the conditions which are present in the early stages of development of the vascular system, when the blood-stream coming from the large veins (which unite in the sinus venosus at the posterior end of the heart), after having traversed this tube, passes through the right and left anterior ventral aortæ, and so by the arterial arches into the two dorsal aortæ, which subsequently unite to form

the single vessel which persists in the adult as the descending thoracic and abdominal aortæ.

It may be supposed also that the embryo, having no cardiac or other principal nerve-centres, is, with regard to its vitality, in a condition somewhat similar to that of a "pithed" frog. It is worse off, however, than a "pithed" frog, for it has no heart with valves and automatic musculo-nervous mechanism by which the blood can be propelled through its vessels in one direction. The blood in the acardiac fœtus is free to flow in either direction; and thus, since the blood coming from the placenta of the living fœtus reaches it by the umbilical artery or arteries, it must of necessity flow in the aorta and umbilical vein in the reverse direction to that of a normal fœtus. The circulation thus established is apparently sufficient, not only to maintain the vitality of the tissues, but also to provide nutritive material for the growth and development of the fœtus.

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(6) Assheton, Richard, "An Account of the Blastodermic Vesicle of a Sheep of the Seventh Day with Twin Germinal Areas," *Journ. of Anat. and Phys.*, vol. xxxiii. p. 363.

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FIG. 3.

FIG. 1.

DR REGINALD J. GLADSTONE.

Fig. 4.

Fig. 2.

Diagram representing the course of the circulation through the composite placenta.

Au.—Umbilical vessels of autosite.
Om.—Umbilical vessels of omphalosite.

Dr Reginald J. Gladstone.

Fig. 5.

Dr Reginald J. Gladstone.

THE PRESENCE OF A VESTIGIAL SIXTH BRANCHIAL ARCH IN THE HETERODONTIDÆ. BY ONÈRA A. MERRITT HAWKES, M.Sc., *Zoological Laboratory, University of Birmingham.*

AMONGST existing Elasmobranch fishes there appears to be only one genus, *Heptanchus* (= *Notidanus cinereus*, Cuv.), which has seven branchial arches, and only two genera, *Hexanchus* (= *Notidanus griseus*, Cuv.) and *Chlamydoselachus*, Garman, in which there are six arches. All the remaining Elasmobranchs have five arches, and, so far as I have been able to ascertain, in no single instance is there any record of the existence of even a vestige of additional arches. In his classical monograph on the skulls of Elasmobranchs,[1] Gegenbaur makes no mention of the presence of vestigial arches posterior to the fifth, and no indication of any such structures is represented in any of the numerous genera whose branchial arches he has figured. If, however, a vestigial sixth branchial arch does exist in any Elasmobranchs which normally have only five arches, it would be reasonable to anticipate that it might occur in such primitive and palæontologically ancient types as the Heterodontidæ. Having recently had occasion to dissect two species of this family, viz. the Californian species, *Gyropleurodus francesci*, Girard, and the Port Jackson shark, *Heterodontus* (*Cestracion*) *phillipi*, Blainv., it was interesting to find this expectation fulfilled, inasmuch as both species possess well-marked remnants of a sixth branchial arch.

The fourth and fifth branchial arches of a young *Gyropleurodus francesci*, 7½ inches in length, are shown in side view in Fig. 1, and it will be seen that two small cartilages (*v.a.*) are attached to the hinder margin of the fifth arch. The upper or more dorsally-placed of the two cartilages is attached by ligament to the inner surface of the ventral extremity of the epibranchial element of the arch, while the ventral cartilage, which is somewhat triangular in shape, with a slightly curved apex, is connected by ligament with the preceding. The two cartilages lie for the most part behind the fifth arch, and incline obliquely backwards and downwards from their connection with it above and in front.

The identity of these cartilages as constituent elements of a branchial arch is not altogether clear. From their position and relations with regard

[1] *Untersuch. vergleich. Anat. d. Wirbelth.*, Pt. iii. *Das Kopfskelet d. Selachier*, Leipzig, 1872.

to the parts of the fifth arch, it is somewhat tempting to regard them as representing the ceratobranchial and hypobranchial elements of a vestigial sixth arch. There is, however, an objection to the identification of the ventral cartilage as a hypobranchial. The retention of a hypobranchial element in a reduced last branchial arch is very unusual, and, as a rule, it is the first element of the arch to undergo suppression. Both in Elasmo-

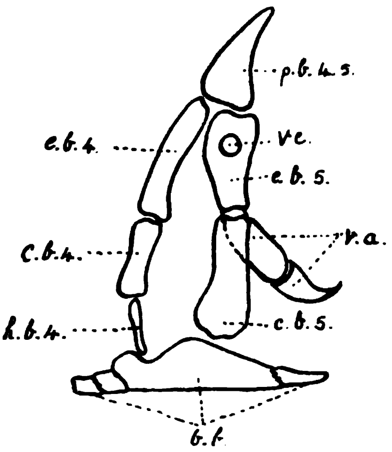

Fig. 1.

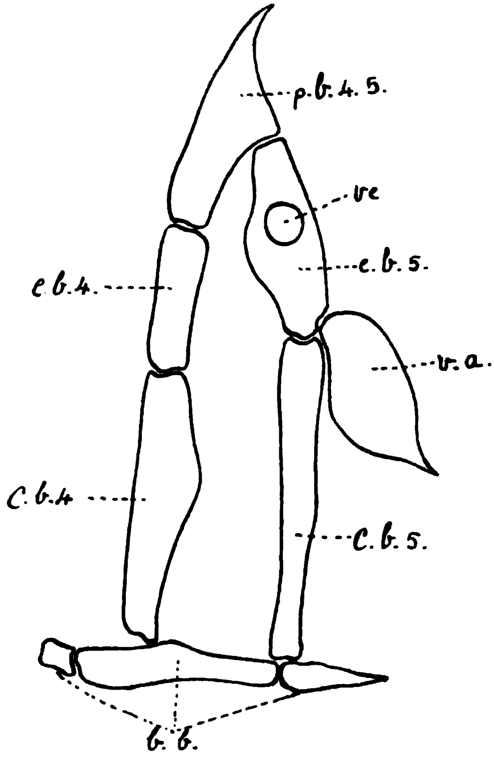

Fig. 2.

branchs and Teleosts the reduced fifth arch has almost invariably lost its hypobranchial factor. Hence its presence in the vestigial sixth arch of *Gyropleurodus* would be somewhat unexpected. It may therefore be the case that the two cartilages really represent the two most persistent elements of a branchial arch, that is to say, the epibranchial and ceratobranchial pieces.

It will be noticed that the epibranchial of the fifth branchial arch has a small perforation (Fig. 1, *ve*) about the middle of its length. This aperture

transmits the external jugular or anterior cardinal vein, as the latter passes ventrally to join the Cuvierian duct, and probably it may be compared with that which occurs between the fourth and fifth epibranchials in *Chimæra monstrosa* and serves a similar purpose. If this be so, the possibility that the fifth epibranchial of *Gyropleurodus* is a composite structure, and includes also the epibranchial pertaining to the vestigial sixth arch, which has fused with it, must not be left out of consideration.

The precise identity of the two cartilages can only be definitely determined when the development of these parts has been satisfactorily investigated; but whatever the result, there can be no doubt that they represent portions of a vestigial sixth branchial arch.

No trace of a sixth branchial cleft between the fifth and sixth arches, either in the form of a pharyngeal pit or otherwise, could be detected.

The condition of the posterior branchial arches in *Heterodontus phillipi* is shown in Fig. 2. In this species a single flattened or leaf-like cartilage (*v.a.*) is attached to the distal end of the epibranchial element of the fifth arch, which apparently corresponds to the more dorsally situated of the two cartilages in *Gyropleurodus*, and therefore represents the sixth arch in a still more reduced or vestigial condition. The epibranchial element of the fifth arch is similar in both species. The branchial arches of a species of "*Cestracion*" are figured by Gegenbaur (*op. cit.*, Plate xix, fig. 3), but the vestigial sixth arch is neither mentioned in the text nor indicated in the figure.

It may be noted in passing, that in the specimens examined there were four basibranchial elements in *Gyropleurodus*, but only three in *Heterodontus*.

It is evident that we have an interesting and continuous sequence of modifications, beginning with *Heptanchus*, which has seven functional branchial arches, passing through *Hexanchus* and *Chlamydoselachus*, each with six functional arches, to *Gyropleurodus francesci* and *Heterodontus phillipi*, each with five functional arches and one vestigial arch, and finally ending with the more typical Selachii in which the five functional arches are alone represented.

The Heterodontidæ have been regarded as being in some respects intermediate between the Notidanidæ and Chlamydoselachidæ on the one hand, and the remaining Selachii on the other. The persistence of a vestigial sixth arch in two species belonging to distinct genera of Heterodontidæ is in harmony with this view.

I have much pleasure in thanking Mr Samuel Garman, of Cambridge Mass., for his gift of a specimen of *Gyropleurodus francesci*, and Professor Bridge for affording me the opportunity of partially dissecting a specimen of *Heterodontus phillipi*.

DESCRIPTION OF FIGURES.

Fig. 1. Side view of the posterior branchial arches of a young *Gyropleurodus francisci*, 7½ inches in length. The fourth and fifth arches, and the vestigial sixth arch are shown. Natural size.

Fig. 2. Similar view of the corresponding arches of *Heterodontus phillipi*.

REFERENCE LETTERS.

b.b. Basibranchials.

c.b. 4–5. Ceratobranchials of the fourth and fifth arches.

e.b. 4–5. Epibranchials of the fourth and fifth arches.

h.b. 4. Hypobranchial of the fourth arch.

p.b. 4–5. Conjoined pharyngobranchials of the fourth and fifth arches.

v.a. Vestigial sixth arch.

v.c. Foramen for the transmission of the anterior cardinal vein.

JOURNAL OF ANATOMY AND PHYSIOLOGY

ON THE FATE OF THE "TÆNIA CLINO-ORBITALIS" (GAUPP) IN ECHIDNA AND IN ORNITHORHYNCHUS RESPECTIVELY; WITH DEMONSTRATION OF SPECIMENS AND STEREO-PHOTOGRAPHS. By Professor J. T. WILSON, *Sydney, N.S.W., Australia*.[1]

IN the primordial cranium of a "mammary fœtus" of Echidna of 5·5 cm. length, Gaupp has described (*Anatomische Hefte*, No. 61, 1902, pp. 198 *et seq.*) the occurrence of a slender cartilaginous bar forming part of the parietes of the brain-cavity. Behind, it is continuous with the postero-lateral boundary of the *sella turcica*, its basal attachment practically corresponding to that of a posterior clinoid process. In front, it passes over, without interruption, into the cartilaginous *ala orbitalis*. It is of relatively considerable length, and it passes obliquely across the extensive hiatus which exists at this stage in the lateral wall of the monotreme chondrocranium; though it is placed in a somewhat more medial plane than the greater part of the periphery of this hiatus. Gaupp has named this cartilaginous bar the *tænia clino-orbitalis*. As seen from without, it serves to divide the great lateral hiatus into a large "spheno-parietal foramen" behind, and a smaller and narrower aperture in front of it, to which Gaupp has applied the name of *fissura pseudo-optica*. The latter transmits not only the optic but also the oculo-motor nerve, and this fact demands, in Gaupp's view, its morphological distinction from a proper optic foramen, as well as the distinction of its posterior boundary as a *tænia clino-orbitalis* from a *tænia metoptica*, which in most mammals forms the posterior boundary of the genuine "optic foramen."

[1] Read at the First International Federative Congress of Anatomy—Geneva, August 1905.

Fig. 4.

Fig. 2.

Diagram representing the course of the circulation through the composite placenta.

Au.—Umbilical vessels of autosite.
Om.—Umbilical vessels of omphalosite.

Dr Reginald J. Gladstone.

Fig. 5.

Dr Reginald J. Gladstone.

sella turcica, whose margin it overspans, springing from the level of the elevated *dorsum sellæ* behind. Here it rests on the dorsal aspect of the ophthalmic division of the trigeminus nerve, whose relatively large size in Ornithorhynchus as compared with Echidna in all probability conditions the difference in the fate of the tænia in the two genera.

EXPLANATION OF FIGURES—TO BE EXAMINED STEREOSCOPICALLY.

Fig. 1. Stereograph (×1·5 diams.) of dissection of floor of cranial cavity of young of Echidna of 40 mm. skull-length. On the left side, exposed by removal of the dura, is seen the *tænia clino-orbitalis* of Gaupp. Under cover of it anteriorly, where it is continuous with the *ala orbitalis*, the optic and oculo-motor nerves pass through the *fissura pseudo-optica.*

Fig. 2. Stereograph (×1·5 diams.) showing portion of the cranial base of an adult Echidna, as seen in a wet preparation after removal of soft parts. The so-called "middle clinoid processes" of van Bemmelen are visible as bony lamellæ bounding the somewhat triangular and roomy *sella turcica.* These lamellæ are the persistent and ossified *tæniæ clino-orbitales.* They are, for the most part, synostosed with the sides of the basi-sphenoid, and the major part of the originally intervening *fissura pseudo-optica* has been practically obliterated, the anterior portion remaining patent and transmitting the nerves. Bristles are, however, inserted in the specimen through imperfect fissural remains of the posterior occluded part of the original fissure.

Fig. 3. Stereograph (×1·5 diams.) of portion of the cranial base of an adult Ornithorhynchus, as seen in a wet preparation after removal of most of the soft parts. The "posterior clinoid processes," relatively long and slender, end in spicular extremities continuous with a white fibrous band—here torn across on both sides—which is the representative in the adult of the fœtal *tænia clino-orbitalis.* Anteriorly this band is attached to a cuspidate projection of the posterior margin of the *ala orbitalis.* The fibrous representative of the tænia rests upon the dorsal aspect of the bulky ophthalmic division of the trigeminus, which has been left *in situ* in the preparation.

NOTE ON THE DEVELOPMENT OF THE THYMUS GLAND IN LEPIDOSIREN PARADOXA. By THOMAS H. BRYCE,[1] M.A., M.D.

IN a recent memoir on the Histology of the Blood of Lepidosiren[2] I have described the origin of the corpuscles at different stages of larval life, the histogenesis of the spleen, and the development of the lymphoid tissue of the kidney. In that paper I made incidental reference to the thymus in the later stages: in this communication I shall deal in detail with the development of the gland, in order to complete the evidence which the material can provide, regarding the origin of the lymphoid elements in this species. I am again indebted to my friend, Professor Graham Kerr, for kindly giving me the use of his sectioned material.

The thymus glands first appear in Lepidosiren at a phase between the stages numbered 34 and 35 of the series.[3] This is a relatively advanced larva, and the late appearance of the gland is perhaps related to the peculiar conditions of the development of the branchial region. Up to stage 32, though the gill region is overlapped by the opercular folds, none of the clefts are patent. The future slits are marked by solid cords of yolk-laden hypoblast, and it is not till stage 33 to 34 that actual fissures are formed. At stage 34 the hyo-branchial cleft is complete, the first branchial is still barred by a septum between an outer and an inner pouch, and the succeeding fissures are not formed. The hyo-mandibular cleft is also a solid cord, of which the two lamellæ are only separated at the outer end; it never becomes a complete fissure, and the epithelial stalk soon disappears. The hyoid arch overlaps the branchial arches, which are telescoped within it and compressed on to the floor of the pharynx. The clefts are very oblique, and, on account of the displacement of the arches, the outer ends of the fissures come to be ventral in position in transverse sections through the pharynx.

While at stage 34 the hyo-branchial clefts are the only openings from the pharynx into the opercular cavities, at a later stage they become reduced, and are ultimately obliterated by the fusion of their epithelial

[1] Read at the First International Federative Congress of Anatomy--Geneva, August 1905.

[2] *Trans. Roy. Soc. Edin.*, vol. xli. part ii., Nos. 11 and 19.

[3] See Professor Graham Kerr's paper on the External Development in *Trans. Roy. Soc.*, B vol. cxcii.

walls. The third clefts then become much wider than the others, and remain henceforward as the chief communications between the pharynx and opercular cavities, the remaining three clefts being merely short vertical fissures in the floor of the pharynx.

At stage 35 the first thymus rudiments appear as solid outgrowths from the dorsal ends of the third branchial clefts—*i.e.* the clefts between the 1st and 2nd branchial arches (fig. 1). Owing to the great obliquity of the

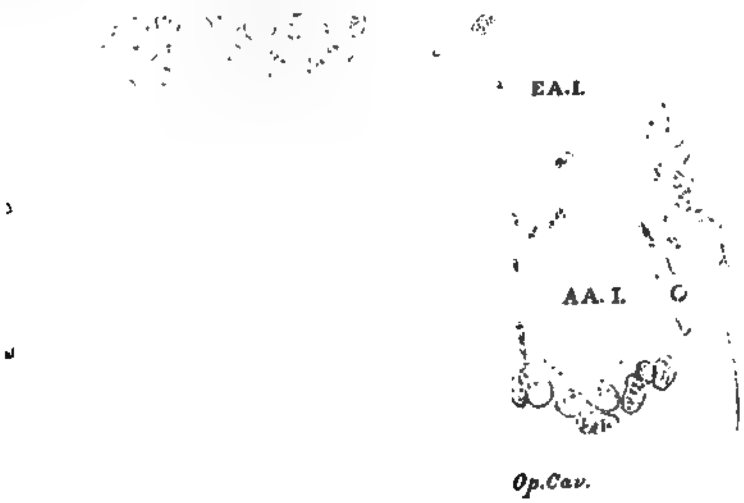

Fig. 1.—Thymus bud from epithelial wall of 3rd branchial cleft: stage 34, series 118 A. Obj. Zeis apo. 8 mm. 6 Oc. *Op. Cav.*, opercular cavity, *3rd B.C.*, 3rd branchial cleft: *D.A.*, dorsal aorta; *E.A.* I., *E.A.* II., efferent vessels of 1st and 2nd branchial arches; *A.A.* I, afferent vessel of 1st arch.

fissures and the telescoping of the arches, the bud is not seen in transverse sections until the actual cleft has disappeared—though the epithelial wall is seen passing transversely inwards from the outer or opercular end of the fissure. To the outer side of each bud a mass of muscular fibres is seen descending into the second branchial arch. The rudiment extends through 16 (10μ) sections, becoming displaced inwards as it is traced backwards—first by the lower part of the muscular bundle, and second, further back by a branch from the vagus group ganglion It then comes to lie between the dorsal aorta and that ganglion.

The cells of the rudiment are epithelioid in character, and rounded or oval in shape. They have a small protoplasmic body, and the cell outlines are difficult to define. Many mitotic figures occur throughout the whole length of the mass. As I demonstrated in my earlier paper, there are leucocytes in great numbers in every tissue of the body long before this stage, yet in the two buds one leucocyte only was found, and it belonged to the eosinophile variety.

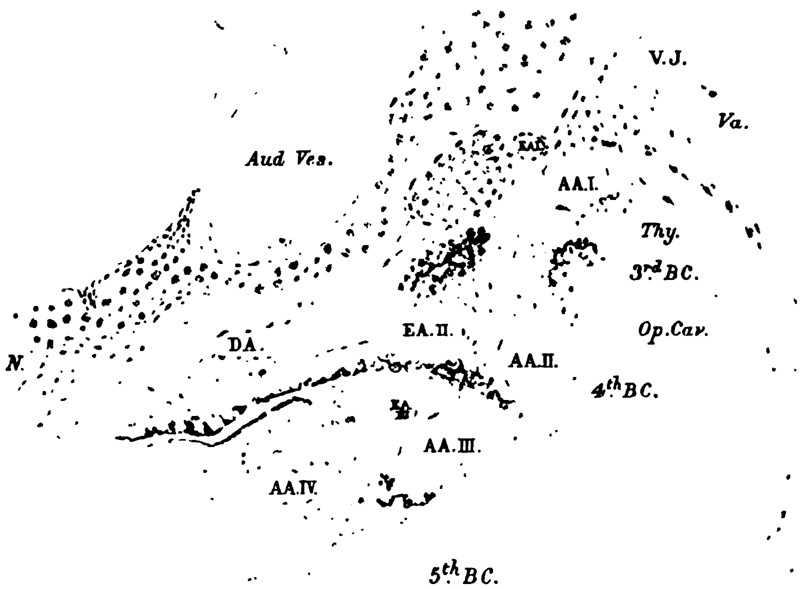

FIG. 2.—Thymus rudiment from 3rd cleft a little way behind its place of origin: stage 35, series 131 c. Obj. Zeis apo. 16 mm. 4 Oc. *Thy.*, thymus; *Op. Cav.*, opercular cavity; *3rd B.C.*, *4th B.C.*, and *5th B.C.*, 3rd, 4th, and 5th branchial clefts; *N.*, notochord; *V.J.*, jugular vein; *Va.*, vagus ganglion; *D.A.*, dorsal aorta; *E.A.*, efferent vessels (*A.A.*, afferent vessels) of branchial arches. The dark particles in epithelium and in thymus are grains of yolk persisting in the hypoblast and its derivatives.

At stage 35 the gland has increased in size; fig. 2 represents a section of the rudiment at this stage. This larva was fixed in osmic acid, and the remains of the yolk in the sections are stained black. The yolk lingers much longer in the hypoblast than in the other tissues, and, as there are remnants of it in the thymus rudiment, we have a further proof that the cells are actually and directly derived from that layer.

The chief bud is derived from the third cleft; but in this series there are traces of a rudiment from the hyo-branchial cleft. It has the form of

a small nodule of hypoblast cells (fig. 3) which extends from the point where the fissure disappears, through several sections. I was at first inclined to regard it as merely the apex of the epithelial wall of the fissure; but as its relations exactly correspond to those of the larger rudiment from the third cleft, I have little doubt that it may be considered an actual thymus bud. It disappears in the next stage and has no part in the fully-evolved gland. Like the other buds, it shows its hypoblastic origin by the yolk grains included in its cells.

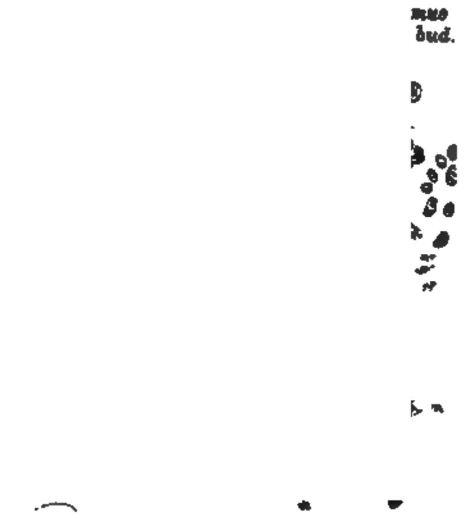

FIG. 3.—Section through 1st branchial arch and 3rd cleft to show thymus bud from hyo-branchial cleft: stage 35, series 131 c. Obj. Zeis apo. 16 mm. 6 Oc.

At stage 36 the bud from the 3rd cleft has grown greatly in size. The cellular mass lies in the roof of the opercular cavity, and passes forward through a few sections in front of its point of origin, but it has no connection with the bud from the hyo branchial cleft: the principal extension is backwards. Anteriorly, it is bounded by the muscular bundle before mentioned, but behind this, it extends outwards to the epithelium of the opercular cavity, and then extends downwards close to the surface The consequence is that when the next muscular bundle is reached the gland is separated into two portions. The inner portion extends inwards dorsal to the aorta, while the outer portion is again divided into two lobes by a nerve from the vagus ganglion (fig. 4). At this stage there is a distinct bud from the

4th cleft, and a possible rudimentary bud from the 5th; this latter is unequally developed on the two sides, and later seems to disappear.

In the next stage, 37, the gland has extended considerably backwards, making its way, as its cells proliferate, in the roof of the opercular cavity, beyond the region of the branchial clefts. Fig. 5 represents a section in which the various lobes are united into one mass, between two of the muscular bundles descending into the arches. From the general relationships it is fairly clear that the bud from the 4th cleft has formed the lower

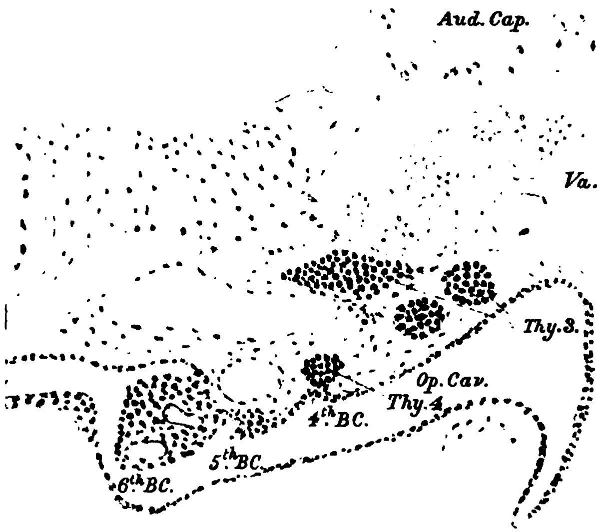

FIG. 4.—Section through branchial region, stage 36, to show thymus rudiment from 3rd cleft (*Thy.* 3) broken up into lobes, and rudiment from 4th cleft (*Thy.* 4). Obj. Zeis *aa.* 6 Oc. × 160 D.

and inner portion of the gland. Posteriorly it is separate from the main mass and forms a separate lobe, but in front it is fused with the rudiment from the 3rd cleft.

The bud from the 5th cleft seems to take no part in the formation of the gland. It is doubtful even whether it can be regarded as a true thymus bud; but at this stage there is present on one side a small epithelial body, the cells of which are dividing actively, and which, I think, probably belongs to this category.

Fig. 6 represents the gland at stage 38—the last of the series—at a point where the mass is broken up into lobes by a muscular bundle and a nerve cord. It has the same general relations as at stage 37, but is considerably

increases in dimensions. It occupies the whole extent of the roof of the pharynx, at early reaching behind to a level posterior to the bifurcation of the aorta, while in front it extends as a thin cellular lamella through some distance anterior to the 3rd cleft, but does not reach by a considerable distance the situation of the now obliterated hyo-branchial cleft.

During all the phases up to this point, the terminal of the series, the cells forming the young thymus retain their epithelioid characters. The cells are rounded with large nucleus and small cell body. The nuclear reticulum is coarse, the chromatin being gathered into large karyosomes.

Fig. 5.—Section through branchial region, stage 37, to show general relation of the fully-evolved thymus gland: stage 37, series 137 A. Obj. Zeis *aa*. 6 Oc

The protoplasm is small in amount, and each cell appears to have a separate cell body. There is, as yet, no sign of the opening out of the cellular mass to form a loose reticulum of branching cells, nor any indication of a differentiation into cortical and medullary zones. Many of the cells are in mitotic phases, and these figures are more numerous than in the surrounding tissues.

In the centre of the lobules are to be noticed a certain number of round solid bodies (fig. 6), the nature of which is not apparent; perhaps they are degenerated nuclei. Throughout the whole gland there are only a few leucocytes, and these are invariably eosinophile cells. There is no indication of any conversion of the epithelioid cells into lymphoid elements.

From the description given by Parker of the gland in the young Protopterus, it would appear that it is composed of lymphoid tissue; and it

Fig. 6. Portion of the gland marked *Thy.* in previous figure more highly magnified. Obj. Zeis apo. 3 mm. Hom. Immer. 6 Oc. Stage 37, series 137 A.

is much to be regretted that the series of larval stages of Lepidosiren should come to an end before there is any indication of a lymphoid transformation of the gland, because the material is eminently suited for a critical decision on this much debated point.

The study of the development of the thymus gland involves three separate problems :—

1st. Origin and number of the primary buds, and their relation to the fully developed gland.

2nd. The origin of the reticulum, and the source of the lymphoid elements.

3rd. The relation of the gland to the appearance of the first leucocytes.

In regard to the first point my results support, clearly enough, the hypoblastic origin of the primary cellular mass. The special features in the development of the branchial region cause a variation in the origin of the buds from the usual type, but in essentials there is no difference.

The buds are solid, and arise from the dorsal end of the branchial clefts. In respect that rudiments are provided by several clefts, Lepidosiren agrees with all the lower vertebrates—the conditions being essentially similar to those prevailing in the Selachians, Teleosts, and Urodeles, (Dohrn, Beard, and Maurer). In respect, however, that the fully formed gland is derived only from the buds from two of the clefts, it differs from the elongated mass in Selachians and Teleosts, and agrees rather with the gland of the amphibians, more especially that of the Urodeles, in which the buds from the 3rd, 4th, and 5th clefts share in the formation of the cellular mass (Maurer), while in the Anura the bud from the 2nd alone forms the gland.

This Lepidosiren material, unfortunately, provides no data towards the solution of the second problem. Throughout all the stages the cells remain rounded cells with oval nuclei, closely packed together, and they have no sort of resemblance to any variety of the leucocytes pervading, in multitudes, all the tissues of the body.

The third question is, however, answered definitely and decisively. *The thymus in Lepidosiren has, up to an advanced larval stage, absolutely nothing to do with the formation of the leucocytes.*

It is most improbable that different conditions should prevail in other forms, and Hammar in a recent paper[1] states that in the frog, chick, dog, cat, and man, the leucocytes appear before there are lymphoid cells in the thymus rudiment. Thus, while lymphocytes do not appear in the human thymus till the third month, primary "wandering cells" (Saxer), ripe leucocytes, and lymphocytes are present in the blood and connective tissues as early as the second month—sparingly in an embryo of 17 mm., but numerous in one of 21 mm. If this be so, this part of the problem of the thymus narrows itself into this—Do the hypoblast cells become converted into a special species of lymphoid corpuscle at a later stage?

[1] *Anat. Anzeiger*, vol. xxvii., parts 1, 2, 3, 1905.

No decisive proof of this is yet forthcoming (see Hammar, *loc. cit.*); and the lymphoid elements being proved antecedent to the thymus in a variety of forms, the onus of proof lies with those who uphold the theory of transformation as opposed to that of substitution.

GLASGOW UNIVERSITY, 1*st July* 1905.

Postscript.—Since the above note was written I have received, through the kindness of Professor Stöhr, his recent paper on the Thymus.[1] His views expressed in that paper are, up to a point, in complete accord with my own results. In amphibians the leucocytes arise in a tract along the hind kidney, while in Lepidosiren I have proved that this is at any rate one site of origin of the lymph elements. Further, the leucocytes are present before there is any indication of the thymus cells having lost their epithelial characters. Taken along with Hammar's[2] recent work, and my own researches, we have thus very strong reason for definitely rejecting the hypothesis put forward by Beard that the thymus is the source of the first leucocytes. Though this is a negative result, it is an important one in so far as it clears the ground. According to Stöhr, all the true leucocytes or lymphoid elements in the thymus are related to the invading blood-vessels and connective tissue; but he makes the novel suggestion that the small cells of the thymus, hitherto regarded as lymphoid cells, are not of that nature at all, but are small epithelial cells derived from the large epithelial cells of the rudiment by division. He thus accepts the results of the observers who describe a transformation of the original cellular elements into small *lymphoid-like cells*, but saves the theory of the origin of the true lymphoid elements from the middle-layer derivatives by denying to the thymus cells kindred with them; in short, the thymus is an epithelial organ throughout, and cannot be included in the same category as the lymphoid organs. In the light of Stöhr's paper, I regret still more that the want of later stages and of adult material, makes it impossible for me to follow out to a decisive issue this part of the problem in Lepidosiren.

[1] *Sitzungs-Berichte der Phys.-Med. Gesellschaft zu Würzburg*, 8th June 1905.
[2] *Loc. cit.*

OBSERVATIONS ON THE CETACEAN FLIPPER, WITH SPECIAL REFERENCE TO HYPERPHALANGISM AND POLYDACTYLISM.[1] By J. SYMINGTON, M.D., F.R.S., *Professor of Anatomy, Queen's College, Belfast.*

THE important deviations from the typical structure of the mammalian fore-limb exhibited by all the Cetacea have naturally attracted the attention of numerous anatomists. Of these deviations the most interesting are the regular occurrence of hyperphalangism and some indications of a tendency to hyperdactylism.

Although comparatively large collections illustrating the development of the cetacean fore-limb have been made by several investigators, especially by Professor Willy Kükenthal, there are still numerous and obvious gaps in the series which, owing to the natural difficulties surrounding the collection of such specimens, can only be gradually filled up by everyone recording any specimens they may happen to obtain. No apology, therefore, is needed for a contribution to this subject, even although, as in my case, the material to be described is limited in amount.

Some time ago I found in the stores of the Museum of this College a fœtal whale which had been preserved in spirit. Unfortunately it was not labelled, and I was unable to ascertain when and where it was obtained. The specimen was a male, and measured 16·5 cm. along the mid-dorsal line from the mouth to the tail; the blow-hole was placed on this line 14 mm. from the mouth. The dorsal fin had not yet appeared. The umbilical cord was attached 7·5 cm. behind the mouth.

Both flippers were removed by a cut made at their attachment to the trunk, stained in borax carmine, dehydrated, clarified, and mounted in Canada balsam. In the case of small fœtuses this method is the simplest and best, as it permits the outlines of the various cartilaginous elements to be determined with great clearness when examined with a hand lens or low-power microscope, and such specimens photograph well (fig. 1).

Small ossific centres were present in the shafts of the radius and ulna, but the skeleton of the flippers distal to these bones was entirely cartilaginous.

Carpus.—There is a distinct ulnar pisiform which articulates wit[h] first phalanx of the 5th digit as well as the ulna. The radial pisifor[m]

[1] Read at the First International Federative Congress of Anatomy—Geneva, August 1905.

absent. The carpus consists of five pieces: the proximal row contains a

FIG. 1.—Photograph of the dorsal aspect of the left flipper of a fœtal toothed whale.

radiale, intermedium and ulnare, the distal row carpalia 2 and 3. The skeletal element articulating with the distal surface of the radiale might

walls. The third clefts then become much wider than the others, and remain henceforward as the chief communications between the pharynx and opercular cavities, the remaining three clefts being merely short vertical fissures in the floor of the pharynx.

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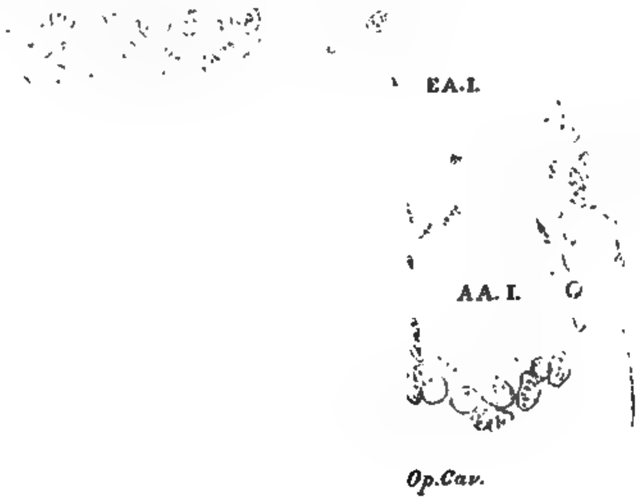

Fig. 1.—Thymus bud from epithelial wall of 3rd branchial cleft: stage 34, series 118 A. Obj. Zeis apo. 8 mm. 6 Oc. *Op. Cav.*, opercular cavity; *3rd B.C.*, 3rd branchial cleft; *D.A.*, dorsal aorta; *E.A.* I., *E.A.* II., efferent vessels of 1st and 2nd branchial arches; *A.A.* I., afferent vessel of 1st arch.

fissures and the telescoping of the arches, the bud is not seen in transverse sections until the actual cleft has disappeared—though the epithelial wall is seen passing transversely inwards from the outer or opercular end of the fissure. To the outer side of each bud a mass of muscular fibres is seen descending into the second branchial arch. The rudiment extends through 16 (10μ) sections, becoming displaced inwards as it is traced backwards—first by the lower part of the muscular bundle, and second, further back by a branch from the vagus group ganglion. It then comes to lie between the dorsal aorta and that ganglion.

The cells of the rudiment are epithelioid in character, and rounded or oval in shape. They have a small protoplasmic body, and the cell outlines are difficult to define. Many mitotic figures occur throughout the whole length of the mass. As I demonstrated in my earlier paper, there are leucocytes in great numbers in every tissue of the body long before this stage, yet in the two buds one leucocyte only was found, and it belonged to the eosinophile variety.

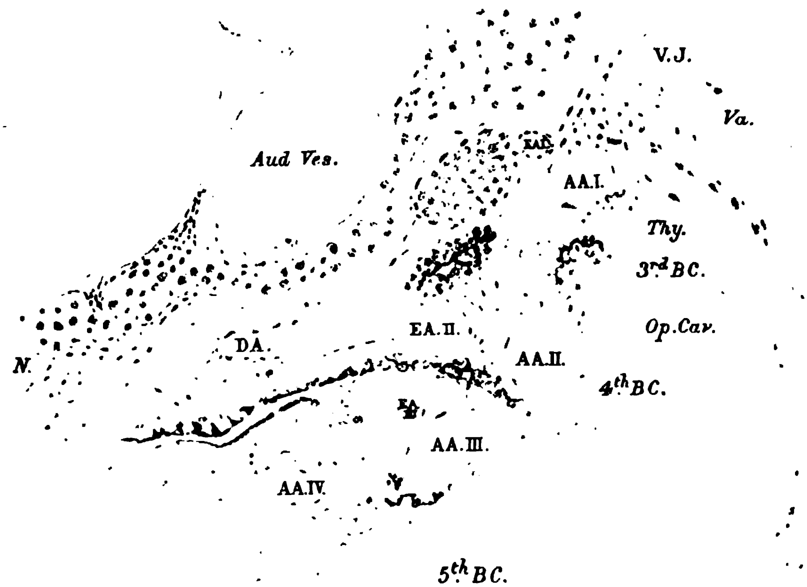

FIG. 2.—Thymus rudiment from 3rd cleft a little way behind its place of origin: stage 35, series 131 c. Obj. Zeis apo. 16 mm. 4 Oc. *Thy.*, thymus; *Op. Cav.*, opercular cavity; *3rd B.C.*, *4th B.C.*, and *5th B.C.*, 3rd, 4th, and 5th branchial clefts; *N.*, notochord; *V.J.*, jugular vein; *Va.*, vagus ganglion; *D.A.*, dorsal aorta; *E.A.*, efferent vessels (*A.A.*, afferent vessels) of branchial arches. The dark particles in epithelium and in thymus are grains of yolk persisting in the hypoblast and its derivatives.

At stage 35 the gland has increased in size; fig. 2 represents a section of the rudiment at this stage. This larva was fixed in osmic acid, and the remains of the yolk in the sections are stained black. The yolk lingers much longer in the hypoblast than in the other tissues, and, as there are remnants of it in the thymus rudiment, we have a further proof that the cells are actually and directly derived from that layer.

The chief bud is derived from the third cleft; but in this series there are traces of a rudiment from the hyo-branchial cleft. It has the form of

segmentation of a cartilaginous ray prolonged in a distal direction from the ungual phalanx similar to that met with in the otter. Indeed, according to Leboucq,[1] this tissue is not cartilage, but dense connective tissue, which extends from the volar surface of the ungual phalanx and from the flexor tendon and presents no indications of transverse segmentation. Ryder thought that the first three phalanges were ossified at the same time as the carpus, and the other phalanges at a later date. Such certainly was not the case in any of the specimens I have examined. With very few exceptions the bony centres for the phalanges of a digit appear in regular order from the basal phalanx towards the terminal one, and the same rule applies to the order in which their epiphyses appear.

There does not seem to be any satisfactory proof of the normal occurrence of more than three phalanges to a digit in any order of mammals, with the exception of the Cetacea. This difference in number is associated with a marked contrast in their respective modes of development, the morphological significance of which has not been appreciated. About twenty-three years ago Mr F. A. Dixey[2] showed that the ossification of the terminal phalanges of the digits in the pig, mole, rat, cat, and human fœtus differed from that of the 1st and 2nd phalanges of the digits, and indeed, from the long bones generally. His description is as follows:—

"Cartilage that is about to undergo calcification presents certain characteristic appearances; the cells with their cell spaces become larger, flatten out, and usually show a tendency to arrange themselves in parallel rows, between which, if the change has already been in progress for some time, the lines of calcification may be seen advancing. But whereas in the long bones as a whole, including the 1st and 2nd phalanges of the digits, the alteration of the cartilage cells, followed by calcification of the matrix, appears first in the centre of the shaft and spreads thence *pari passu* towards the two extremities, in the ungual phalanx it is seen to arise in the tip or distal extremity of the cartilage, from which point it spreads gradually backwards towards the base of the phalanx. Similarly the subperiosteal deposit of membrane bone in all other cases begins as a thin and narrow ring surrounding the shaft and placed midway between the two extremities—that is to say, in direct relation with the spot where the cartilage first begins to ossify; in the ungual phalanx, however,

[1] "Ueber das Fingerskelett der Pinnipedier und der Cetaceen": *Anat. Anzeiger*, 1888; and *Résultats du Voyage du S.Y. Belgica—Zoologie: Organogénie des Pinnipèdes*, I. "Les Extrémités," 1904.

[2] "On the Ossification of the Terminal Phalanges of the Digits." By F. A. Dixey, B.A. Oxon. Communicated by E. A. Schäfer. *Proceedings of the Royal Society of London*, vol. xxxi.

4th cleft, and a possible rudimentary bud from the 5th; this latter is unequally developed on the two sides, and later seems to disappear.

In the next stage, 37, the gland has extended considerably backwards, making its way, as its cells proliferate, in the roof of the opercular cavity, beyond the region of the branchial clefts. Fig. 5 represents a section in which the various lobes are united into one mass, between two of the muscular bundles descending into the arches. From the general relationships it is fairly clear that the bud from the 4th cleft has formed the lower

FIG. 4.—Section through branchial region, stage 36, to show thymus rudiment from 3rd cleft (*Thy.* 3) broken up into lobes, and rudiment from 4th cleft (*Thy.* 4). Obj. Zeis *aa.* 6 Oc. × 160 D.

and inner portion of the gland. Posteriorly it is separate from the main mass and forms a separate lobe, but in front it is fused with the rudiment from the 3rd cleft.

The bud from the 5th cleft seems to take no part in the formation of the gland. It is doubtful even whether it can be regarded as a true thymus bud; but at this stage there is present on one side a small epithelial body, the cells of which are dividing actively, and which, I think, probably belongs to this category.

Fig. 6 represents the gland at stage 38—the last of the series—at a point where the mass is broken up into lobes by a muscular bundle and a nerve cord. It has the same general relations as at stage 37, but is considerably

The proximal ends of the radius and ulna were covered with a thin layer of cartilage and united by strong ligamentous tissue to the humerus, and their distal ends had epiphyses. The carpus consisted, as usual, of five elements, all partially ossified, but the ulnar pisiform was cartilaginous. The phalangeal formula was:

I	II	III	IV	V
1	7	6	3	2

The phalanx of the 1st digit contained a diaphysial centre ·8 cm. long, while the proximal cartilaginous portion measured 1·3 cm. and the distal 1·1 cm., so that only one-fourth of the length of this phalanx was ossified. Diaphysial nuclei were present in all the phalanges of the 2nd, 3rd, 4th and 5th digits, those towards the distal end, however, being very small. All the phalanges were cartilaginous at their extremities, and the only epiphysial centres which had appeared were those at the proximal and distal ends of the first phalanx of the 2nd digit. The terminal phalanges of the three middle digits tapered distally, and showed some indications of a transverse septum, and consequently a probable additional phalanx, which, however, was entirely cartilaginous. I am indebted to my colleague, Professor Gregg Wilson, for the opportunity of examining this specimen.

2. *Bottle-nosed dolphin* (*Tursiops tursio*).—Two of these whales were caught in Dublin Bay in the spring of 1905.[1] The flippers of the female, which was 10 feet 6 inches long, were secured for the Dublin Museum of Science and Art, and through the kindness of Dr Scharff I was able to examine the skeleton in the fresh condition. These flippers were about 45 cm. long, measured from the proximal end of the humerus to the apex of the flipper. There were five carpal bones all ossified, but the ulnar pisiform was cartilaginous. The phalangeal formula was:

I	II	III	IV	V
1	10	7	4	4

The phalanx of the 1st digit was only about 3·0 cm. long. It possessed a diaphysial centre and a proximal epiphysis, but the distal end was tipped by a small piece of cartilage. The 2nd, 3rd and 4th digits illustrated a characteristic feature of the cetacean hand in that the ossification of the phalanges is most advanced at the proximal ends of the digits, and gradually becomes less developed towards the distal ends, the terminal phalanges being more or less entirely cartilaginous. In the 2nd digit the first six phalanges have each a diaphysis and two epiphyses proximal and distal, the seventh and eighth only diaphysial centres, and the last two are entirely

[1] *Irish Naturalist*, June 1905.

cartilaginous. In the 3rd digit the first four phalanges have each three bony centres, the fifth and sixth only one, that of the sixth being very small, and the terminal phalanx is cartilaginous. The two proximal phalanges of the 4th digit have each three centres, the 3rd has a small diaphysial centre, and the minute fourth phalanx is cartilaginous. In the 5th digit ossification is less advanced; the first phalanx contains a diaphysial nucleus and the remaining three are cartilaginous.

FIG. 2.—Right flipper of Tursiops tursio. Ventral surface.

Kükenthal[1] has figured the distal portion of the 2nd and 3rd digits of the hand of an adult dolphin (Delphinus delphis) showing a similar progressive ossification from apex towards base.

Both Leboucq[2] and Kükenthal[3] have found traces of nails in young

[1] *Op. cit.*, p. 308, fig. 41.

[2] "Ueber Nagelrudimente an der fœtalen Flosse der Cetaceen und Sirenier," *Anat. Anzeiger*, Bd. 1889.

[3] *Op. cit.*, p. 302.

fœtal whales situated over the terminal phalanges of the digits, but these soon disappear.

If we assume what is extremely probable, that whales have descended from some order of land mammals, it is evident that the disappearance of a cutaneous appendage to the ungual phalanx in the form of a nail, claw, or hoof has been associated with the arrest in development of the subperiosteal growth of a bony cap on the distal end of the terminal cartilage, such as Dixey showed to be formed in ordinary mammals. The simple cartilaginous bar at the distal end of the digits of whales thus represents the persistence of the primitive condition of ordinary mammals. Such a condition would obviously facilitate the development of additional cartilaginous elements to adapt the limb to its newly acquired function as a balancing and steering organ.

Authorities are by no means agreed as to the number of phalanges possessed by the different members of the Cetacea, and even after making allowances for discrepancies arising from unsatisfactory or incomplete methods of examination, it would appear that the number is liable to considerable variation. The liability to such variation is readily understood when the developmental history of the phalanges is studied. Thus, according to Kükenthal,[1] the number of phalanges increases during early fœtal life, and undergoes a subsequent reduction before birth. In an embryo of phocœna communis 2·5 cm. long, the number of phalanges in the digits from 1st to 5th was 3, 6, 6, 5, 3; in an embryo 4·7 cm., 3, 8, 8, 5, 3; in one 7 cm., 3, 9, 8, 5, 4; and in another 12·7 cm., 3, 10, 9, 5, 4. After this period the numbers appeared to diminish, for in a fœtus 68 cm. long the formula was 2, 9, 8, 5, 2, and in an adult 2, 8, 6, 4, 2. In my case of a nearly adult porpoise there was only one phalanx in the 1st digit, while according to Kükenthal's table the number for this digit may be two or three. I could not satisfy myself of the existence of more than seven phalanges in the 2nd digit, and Kukenthal reckons eight for the adult. In the 5th digit he states the number for the adult as two, the same as in my specimen, but four existed in a young animal 128·3 cm. long. It is extremely probable that not only are there differences in the number of cartilaginous segments which are formed, but that also the subsequent process of reduction varies in its extent and in the period of life when it occurs.

Both Kükenthal and Leboucq have recorded cases of a partial longitudinal division of the 5th digit in various species of whales. The flippers of a toothed whale described early in this paper are very good examples of this condition. Its occurrence is of special interest owing to the evidence afforded by the study of certain fossil reptilians, as in these animals the change

[1] *Op. cit.*, p. 294.

from a semi-terrestrial to a purely aquatic life was associated not only with marked hyperphalangism, but also with a tendency to an increase in the number of digits. Thus in the orders of the plesiosaurians there is exhibited a gradual transformation of the limbs into hyperphalangeal paddles, but they remain pentadactyle. In the ichthyosauria, which were absolutely aquatic, not only is the hyperphalangism still more marked, but there is an increase of digits to six or more. None of the whales present such a degree of hyperdactylism as the ichthyosaurs. In the former it is only occasionally that the 5th digit is found partially divided, and in none of the recorded cases is it complete. I have only met with it in one animal. Through the kindness of Mr Oldfield Thomas I had the opportunity of examining, in the stores of the South Kensington Natural History Museum, the following fœtal specimens:—Two white whales, four lagenorhynchi, and two globiocephali, and in none of them did I recognise any evidence of this condition. I have in my possession the flippers of a small fœtal white whale, mounted in balsam. The 5th digit exhibits no traces of a longitudinal division, but its first phalanx (metacarpal) is broader than those of the other digits. In twelve toothed whales, ten fœtal and two more or less fully grown, which I have examined, only one exhibited a tendency to a longitudinal splitting of the 5th digit. So far, therefore, as one is justified in expressing an opinion from such a limited number of observations, it would appear that the evolution of an additional or sixth digit is still in a very elementary stage in these animals.

NOTE ON THE ELASTIC TISSUE IN THE EYE OF BIRDS.[1] By

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PART II.

HOUSE SPARROW—*Passer domesticus.*

DESCEMET'S membrane is very thin, and feebly stained. In the sclerotic, elastic tissue is abundant and begins high up—even, perhaps, in the rim of the cornea. The fibres form networks that run from before backwards throughout the inner half of the sclerotic coat: slightly further back another mass of fibres arises that passes off into the conjunctiva, leaving the outer part of the sclerotic free from elastic tissue. On the inner aspect the elastic network does not extend far backwards, but slopes away inwards to run down the inner surface of the sclerotic.

The elastic fibres crossing the angle are very fine and numerous, almost filling it; they pass over to the ciliary ground plate, where they unite with a network of fine arcuate fibres interspersed with pigment cells. From this network, elastic fibres run into the ciliary processes in some number; others run into the base of the iris, where they end; many run backwards along the choroid to the elastic tendon of insertion of the ciliary muscle, with which they blend.

The ciliary muscle arises from practically non-elastic tissue and passes to its insertion into a bundle of coarse elastic fibres, which can be traced in the choroid to the level of the ora, where they terminate by blending with the fine fibres surrounding the choroidal vessels; it is also inserted into the sclerotic by a long branch which contains rather more fibres than that ending in the choroid—the insertion is into the perichondrium of the inner surface of the cartilage cup, as usual.

The conjunctiva is also very elastic.

This eye, for its size, contains much elastic tissue.

THE CHAFFINCH—*Fringilla cœlebs.*

Descemet's membrane is reduced to a mere line, and is faintly stained.

From the inner half of the corneo-sclerotic junction, and from the

[1] The figures referred to in the text accompany Part I. of this paper, which was published in the last number of the *Journal* (*Oct.* 1905).

corneal tissue immediately in front of it, numerous fine elastic fibres spring to run backwards; numerous at first, they very soon decrease in number, and almost disappear at the level of the origin of the pectinate ligaments. The elastic fibres that cross the angle take origin from a narrow network of coarse fibres that start at the termination of Descemet's membrane, increase in number, and extend backwards to the level of the posterior border of Schlemm's canal; they do not enclose this canal, there being only a few longitudinal and very thin elastic fibres in the sclerotic coat external to it. Most of the fibres that enter into the formation of this coarse network have a circular course.

The fibres crossing the angle are coarse, and pass to the ciliary ground plate, where they quickly disappear among the pigment cells. The ground plate contains only a very faint elastic network, long strands from which run backwards towards the choroid; no fibres appear to reach the iris from any direction.

The ciliary muscle takes origin from non-elastic fibres, and ends, as usual, in an elastic tendon that divides into two branches—a small one going to the sclerotic, and a larger one reaching to the level of the ora serrata, where it practically disappears.

The elastic fibres of the conjunctiva are few and thin; they have a longitudinal course under the epithelium.

THE GOLDFINCH—*Fringilla carduelis.* (Fig. 4.)

In this bird Descemet's membrane is very thin and almost invisible. The elastic fibres of the sclerotic arise from the inner half of its junction with the cornea; they are few in number, and pass backwards in the loose connective tissue from which the ciliary muscle springs. Along the inner margin of the sclerotic are many somewhat coarse elastic fibres circularly arranged; they extend backwards as a thin layer to beyond Schlemm's canal, where all trace of them becomes lost, but the dense sclerotic tissue between the bony ring and the ciliary muscle is full of small, circular, scattered elastic fibres that disappear from it at the level of the rim of the cartilage cup.

The elastic fibres that cross the angle are coarse for such a small eye, and few in number; they pass to the ciliary ground plate, where they become lost amongst the pigment cells. A few fibres from the network in the ground plate pass forwards to enter the base of the iris; others pass backwards along the choroid towards the tendon of insertion of the ciliary muscle, in which they end. The elastic fibres of this tendon mostly end in the choroid. though a few short ones run towards the cartilage cup, in he

periosteum of which they terminate. The conjunctiva and the tissue outside the eyeball contain many elastic fibres.

THE SKYLARK—*Alauda arvensis*.

The membrane of Descemet is thin, and terminates abruptly. Elastic fibres make their appearance in the sclerotic at its junction with the cornea; they lie chiefly in its inner half, and most of them run antero-posteriorly; they may be traced in the sclerotic as far as the hinder border of the canal of Schlemm, and lie external to it.

Coarse, circular, elastic fibres are found along the inner margin of the sclerotic; starting from the termination of Descemet's membrane they are scattered in a narrow band that extends backwards along the inner border of Schlemm's canal, and finally disappear just posterior to it.

The fibres crossing the angle are coarse for such a small bird; they are directed backwards and inwards towards the ciliary ground plate only, none apparently running forwards to the iris, which, however, contains a few thin elastic fibres at its base that are derived from the network in the ground plate. The elastic network of the ground plate is by no means a rich one, and is much obscured by pigment cells; from it, in addition to those going to the iris, a few fibres pass into the ciliary processes, whilst others run backwards to the choroid, in which they end. They are very thin and inconspicuous.

The ciliary muscle arises from white fibres amongst which no elastic fibres can be seen, and passes backwards to be inserted into a coarse fibred elastic tendon that divides into a long branch ending in the choroid at the level of the ora, after thinning off considerably, and into a shorter one consisting of comparatively few fibres that unite with the perichondrium of the cartilage cup.

THE SWALLOW—*Hirundo rusticus*.

Descemet's membrane is distinctly elastic in nature, and splits posteriorly into fibres that help to form the network on the inner surface of the sclerotic. The elastic fibres of the sclerotic begin well forward from the inner half of its junction with the cornea; at first they are all circular, but soon become intermingled with arcuate fibres, the number of which increases whilst the circular ones become fewer and fewer; they extend throughout the whole breadth of the inner half of the sclerotic and unite with a band of thick circular fibres along its inner edge, and Schlemm's canal, which is of large size, is encircled by them. The broadest of these fibres lie on the inner side of the canal, beyond which they soon cease,

though many fine circular elastic fibres continue to be present between the white ones as far backwards as the level of the bony plates.

Very many elastic fibres cross the angle, almost filling it; they pass to the ciliary ground plate, which is thin and furnished with an elastic network only in its outer part, from which a few run forwards to the base of the iris, and others are directed backwards in the choroid to the insertion of the ciliary muscle; but no fibres for the ciliary process are given off from it.

The tissue from which the ciliary muscle springs contains some elastic fibres, and the muscle passes backwards to end in the usual elastic tendon. The conjunctiva, and the sclerotic immediately adjacent to it, are full of elastic fibres that have a circular course.

THE BLUE-TIT—*Parus cœruleus.*

Descemet's membrane is practically absent from the eye of this bird.

Elastic fibres begin on the inner surface of the sclerotic at its junction with the cornea, and pass backwards in the form of a narrow network internal to the fibres of origin of the ciliary muscle. For so small an eye the elastic fibres are thick, run an oblique or circular course, and can be traced past the canal of Schlemm to a point beyond, situated a distance equal to its antero-posterior diameter. The elastic fibres crossing the angle spring from this network.

A few arcuate elastic fibres are present among the fibres of origin of the ciliary muscle, which is of considerable size, and passes backwards to be inserted into an elastic tendon which bifurcates behind into a very thin external strand that passes to the sclerotic cartilage, and a thicker one that runs in the choroid to the level of the ora, where it suddenly diminishes in size to a few fibres which join the choroidal vessel walls. The outer part of the sclerotic is entirely devoid of elastic tissue.

THE WREN—*Troglodytes vulgaris.*

The posterior corneal lamina is very thin and faintly stained. The elastic fibres of the sclerotic arise along the inner two-thirds of the oblique line that marks its junction with the cornea; they are arranged as inwardly directed lines of circular fibres of medium size, which extend to the level of the most anterior fibres of origin of the ciliary muscle. Thereafter they are succeeded by a network of coarse elastic fibres lying on the inner surface of the sclerotic, and extending backwards for a short distance only; from this network the fibres of the pectinate ligaments spring.

Many elastic fibres are present in the white fibrous tissue from which the ciliary muscle takes origin, and a few accompany its fibres for some little distance. The elastic tendon of insertion of the muscle is thick for such a small bird, and bifurcates posteriorly into two almost equal bundles —the one passing to the choroid, and the other becoming inserted into the perichondrium of the sclerotic cup.

The tissues around the eyeball are full of elastic fibres that form a thin felted layer around it.

THE WILD DUCK—*Anas boscas*.

In all probability the membrane of Descemet is not elastic, but near its termination posteriorly a thin thread of elastic tissue lies between it and the cornea. From this thread a network of fibres springs which runs backwards, and from this the elastic fibres crossing the angle mostly arise; they pass through the ciliary ground plate to end in the processes just external to the uvea. In front of these are the pectinate ligaments that pass across to the iris; they consist of white fibrous tissue intermingled with elastic threads, and fuse with that of the iris.

In the ground plate, the elastic fibres of the angle come into relation with other coarse elastic fibres that have a circular direction, forming with them a network that can be traced backwards towards the choroid, in which, after becoming much less numerous, they end in relation to the tendon of insertion of the ciliary muscle.

The sclerotic external to the canal of Schlemm and ciliary muscle contains only a few very fine elastic fibres mingled with the white ones, most of which take an oblique course round the eyeball, and are so fine that a $\frac{1}{12}$ objective is needed to see them. They do not extend very far backwards.

The ciliary muscle arises from white fibrous tissue containing many fine elastic threads and is inserted chiefly into the choroid by a rather thin elastic tendon, the fibres of which can be traced on the outer side of the choroidal vessel as far back as the ora; a few fibres only pass into the sclerotic to unite with the perichondrium of its cartilage cup. The conjunctiva contains many elastic fibres.

This night flying bird has very little elastic tissue in its eyeball when compared with the chick or the pigeon, probably because elastic tissue is only essential when strong positive accommodation is frequently resorted to, which is not the case with this bird, for it obtains its food from the mud of pools and rivers rather by feel than by sight.

THE COMMON GULL—*Larus canus*. (Fig. 5.)

Descemet's membrane is elastic throughout and thickened posteriorly to double its breadth; it breaks up into fibres that unite with a network of coarse fibres lying along the inner surface of the sclerotic and extending to beyond Schlemm's canal.

From the corneo-sclerotic junction along its whole breadth, and even from the corneal tissue in front of it, elastic fibres having a circular course make their appearance in considerable number, and continue to pervade the sclerotic between the ciliary muscle and the bony plates as far backwards as the anterior margin of the cartilage cup, along the outer surface of which they intermingle with arcuate fibres of the same nature that reach to the back of the eyeball.

The elastic fibres crossing the angle spread out considerably; the most anterior consists of single thin fibres or of bundles of them covered with endothelium, and pass to the iris, into which they penetrate, and in which they may be traced for some distance just beneath the anterior epithelium. The other fibres which do not crowd the angle pass across it to the ground plate of the ciliary processes, where they merge with its elastic network; this consists chiefly of somewhat scattered arcuate fibres with pigment cells between them, and from it some fibres pass into the processes, whilst others enter the base of the iris, and, running forwards in it for some little distance, diverge from one another to make room for many coarse circular elastic fibres that make their appearance between them; others run backwards in the choroid, become attenuated in their course, and finally end by merging with the tendon of insertion of the ciliary muscle.

The muscle arises in non-elastic tissue and is inserted into a thick elastic band, fibres from which extend forwards for some distance along the muscle fibres. Nearly all the fibres of the tendon end in the choroid; they lie external to the vessels, with the walls of which they gradually become united, to disappear entirely at the level of the ora; a few fibres pass to the sclerotic, where they end in the perichondrium.

THE TERN—*Sterna fluviatilis*.

Descemet's membrane, which is thick, is only slightly stained, and is succeeded by a thin elastic net that runs backwards on the inner surface of the sclerotic. In the sclerotic are many circular fine elastic fibres which extend between the bony plates and the muscle to the level of the cartilage, where they end.

The elastic fibres crossing the angle spring from the coarse network, are few in number, and do not crowd the angle. Some reach the base of the iris,

where they end; the others go to the ground plate, where they merge with the somewhat numerous elastic fibres in it. From this a few fibres enter the processes, and others run backwards in the choroid to the tendon of insertion of the ciliary muscle.

Some of the fine elastic fibres present in the tissue, from which the ciliary muscle takes origin, are continued along the muscle fibres for a short distance. The elastic tendon into which the muscle is inserted splits into two almost equal strands to end—the one in the perichondrium of the sclerotic cup, the other in the choroid, in which it may be traced to the level of the ora.

The conjunctiva contains only a moderate amount of elastic tissue.

The Budgerigard.

The posterior lamina is elastic throughout, and unites posteriorly with the fibres in the angle.

From the inner half of the corneo-sclerotic junction some elastic fibres arise that pass backwards in the loose tissue from which the muscle springs. On the inner surface of the sclerotic are many closely-packed elastic fibres that have a circular course and extend backwards in a narrow layer that opens out to enclose Schlemm's canal, the fibres on the inner side of which are circular, whilst those on its outer aspect are thin and directed backwards. The tissue also between the muscle and the bony plates is full of fine scattered circularly running elastic fibres, that can be traced as far back as the lip of the cartilage cup.

The elastic fibres that cross the angle are numerous though not crowded: a few pass to the base of the iris, and run up in it just external to the uvea; the others pass into the ground plate and through it into the ciliary processes, which contain many fibres. The network of the ground plate is full of pigment cells; it passes forwards to the iris base, and backwards in the choroid to the tendon of insertion of the ciliary muscle.

The muscle arises from the loose white fibrous tissue on the inner aspect of the sclerotic and is inserted into the usual elastic tendon, all the fibres of which, with the exception of a few that end in the sclerotic, run on the outer aspect of the choroid, and, gradually becoming less numerous, finally end at the level of the ora serrata.

The conjunctiva contains many small circular fibres, whilst the connective tissue outside the sclerotic has but few.

Of all vertebrates the Sauropsida alone possess striped muscle fibres within the eyeball, which by their powerful and rapid contraction permit

of the change from negative to positive accommodation to take place very suddenly; but at the same time a certain amount of shock must be imparted to the delicate structures within the globe, which might interfere with clearness of definition were not some means provided of absorbing it and of converting the sudden pull of the muscle on the choroid into an even, continuous strain, which is effected by a great increase in the amount of elastic tissue within the eye. When compared with the eyes of other vertebrates, that of the bird is seen to contain an enormous quantity of elastic fibres and to be provided with a special elastic tendon for the insertion of the ciliary muscle: this is also present to some extent in lizards, but no trace of such an arrangement can be found in fishes, amphibia, and mammals.

In most birds the membrane of Descemet stains deeply with Weigert's elastic stain, and therefore consists mainly of elastin; but, in a few cases, only that part of it which is in contact with the cornea stains at all deeply, the remainder being very pale or even not stained at all, in which it resembles the posterior lamina in most mammals. When traced backwards, the deeply-stained part splits into a number of elastic fibres that unite with others derived from the inner half of the sclerotic to form a conspicuous elastic network, which extends along the inner surface of the sclerotic from its junction with the cornea to the posterior border of the canal of Schlemm. From this network coarse elastic fibres pass across the angle to become lost in the ciliary ground plate, where they come into relation with another similar though less conspicuous network.

Of the fibres that cross the angle, some are very thick and run singly: others, which are thinner, unite together to form bundles of varying thickness; all are covered with endothelium, and have the spaces of Fontana between them. The pectinate ligaments of birds, therefore, mainly consist of elastic tissue, whereas in mammals they usually consist of white fibres upon which lie thin elastic threads in varying quantity. Birds that feed by picking up small particles from the ground, or from the bark of trees and shrubs, possess large ciliary muscles, as they require to use strong, positive accommodation to enable them to see their food clearly at so short a distance, and in them the pectinate ligaments are thick, numerous, closely packed together, and in some cases they quite fill the angle.

In many birds the most anterior pectinate ligaments pass to the base of the iris, where they seem to end quite suddenly; in a few cases, however, they can be traced in it for some little distance, but in all birds the iris may be said to be practically devoid of elastic tissue, other than that in the blood-vessel walls, except at its base. Of the pectinate ligaments that go to the ground plate, some appear to run through it to end in the tips of the

ciliary processes, which is especially the case in ground-feeding species; other birds would appear to have little or no elastic tissue in these processes. From the elastic network in the ground plate, which varies much in amount in different birds, fibres pass forwards to end in the base of the iris, and others pass backwards in the choroid to mingle with the fibres of the elastic tendon of insertion of the ciliary muscle.

The outer part of the sclerotic as a rule contains few elastic fibres, and those present are very fine. In some birds, however, they are numerous, and may be traced backwards to the level of the anterior edge of the cartilage cup, or even further; most of these fibres have a circular course. Between the ciliary muscle and the bony plates, fine circular elastic fibres are present in some birds but not in all, and are always somewhat scattered and inconspicuous.

The ciliary muscle which always springs from white fibrous tissue, amongst the fibres of which there may be some elastic threads, invariably ends in a conspicuous bundle of somewhat coarse elastic fibres that bifurcates posteriorly to be inserted, the one part into the choroid, and the other into the perichondrium of the inner surface of the sclerotic cartilage cup (fig. 8). These two divisions vary considerably in relative thickness; in ground-feeding birds the sclerotic bundle is often as big, or even bigger, than that entering the choroid, and no doubt plays an important rôle in their economy; in other birds the choroidal portion is usually much the bigger, and in some cases the sclerotic strand may be reduced to a few fibres only. When the muscle contracts, both these bands will be simultaneously put on the stretch: the one passing to the choroid will draw that structure forwards with an even, non-jerky pull, thus allowing of rapid and strong positive accommodation; but the band passing to the sclerotic, not being able to draw the cartilage forwards, will be put more and more on the stretch as the muscle shortens, and will act as a spring with a fixed point behind by which negative accommodation may be instantly restored the moment the muscle ceases its contraction, and is a much more efficient mechanism for this purpose than that possessed by any other animal.

One need only watch a sparrow or a robin when feeding on the ground to be convinced of the paramount importance to these birds of the quick re-establishment of negative accommodation, surrounded as they are by lurking and active foes that spring upon their prey from a distance, and from which they could not hope to escape did they not perceive them in time to take wing; and by the law of natural selection only those birds would escape whose eye movements were sufficiently rapid to give them timely warning of approaching danger.

With regard to the controversy concerning the presence or absence of

elastic fibres in the cornea, I am confident that no elastic fibres stainable by Weigert's method are present in it except at the edge; no doubt by other methods elements resembling elastic tissue can be demonstrated there, as by staining with orcein after Weigert's, or by the method advocated by Tartuferi, which, however, in my hands has not given the results claimed for it by its inventor. I therefore incline rather to the views expressed by Sattler and Stutzer that the tissue stained by Tartuferi is not elastic in the same sense as that stained by Weigert's method, but that being stainable when Weigert's is reinforced by orcein, is of a nature, chemically, closely allied to though not identical with elastin. For references dealing with this subject, see Colombo, *Annali di Ottalmologia*, xxxii. p. 381; Stutzer, *Archiv f. Ophthalmologie*, xlv. p. 322; Kezoji Kiribuchi, *Archiv f. Opthal. u. Otolo*, xxxi. p. 238; and Tartuferi's reply, *Annali di Ottalmologia*, xxxiii. p. 331.

PULMONARY CHANGES IN ASPHYXIA.

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ASPHYXIA may result from any condition or conditions interfering directly or indirectly with the supply of arterialised blood to the centre governing the respiratory mechanism. The effects of asphyxia are seen all over the body, but are most marked in the circulatory and respiratory systems. The following paper is devoted to a consideration of the pulmonary changes seen in six cases of asphyxia.

SYMPTOMATOLOGY OF ASPHYXIATION BY SUFFOCATION.

The symptoms of asphyxia are the manifestations of an attempt, chiefly on part of the respiratory and circulatory systems, to meet the demand for a supply of arterialised blood to the respiratory centre, and may be looked on as an aggravation of the symptoms of dyspnœa accompanying increased venosity of the blood in any disease. These phenomena occurring in a normal animal after occlusion of the trachea may be divided into two stages—(1) a stage of irritation, and (2) a stage of paralysis.

(1) *Stage of Irritation.*—In less than half a minute from the time that the supply of oxygen has been cut off, the symptoms of dyspnœa appear. The respiratory movements are increased in depth and in a less degree in rhythm. As the venosity of the blood increases the dyspnœa becomes greater, the expiratory phase of the respiratory movement being relatively exaggerated. All the accessory muscles of respiration are brought into action, and finally almost every muscle in the body takes part in the struggle, which culminates in convulsive movements of a pronounced expiratory type. Early in the second minute after deprivation of oxygen the convulsive movements cease somewhat abruptly and the stage of paralysis sets in.

(2) *Stage of Paralysis.*—A state of unconsciousness has now supervened. The muscles are more or less flaccid and the sphincters are relaxed, while the pupils are dilated and there is absence of response to nervous stimulation. The type of respiration has completely changed; at long intervals there is a prolonged inspiratory effort followed by a passive

expiration, the inspiration being of the nature of a gasp accompanied by contraction of the accessory muscles of inspiration. The respirations gradually become slower and more shallow, and death ensues with a convulsive inspiratory gasp.

These changes, from the time of the occlusion of the trachea till death, occupy in the case of a full-grown dog between four and five minutes. There is, however, a considerable degree of variation in different animals, and in the same animals under different circumstances; thus, a rabbit will succumb sooner than a dog, and a newly-born puppy has recovered after 50 minutes' immersion, while in the case of a full-grown dog death usually ensues after 1½ minutes (Foster).

Effects of Asphyxia on Circulatory System.

The effects of asphyxia on the circulatory system are mainly due (1) to the mechanical interference of the abnormal thoracic movements, and (2) to the carbonic acid poisoning of the vaso-motor centre.

(1) *Mechanical Effects.*—The effects of the respiratory movements on the blood pressure are seen in quiet, normal respiration, and these effects are modified according as the respiration is rapid or slow, shallow or deep, easy or laboured. The chief determining factor in the rise and fall of blood pressure is the variation occurring in the pressure exerted on the large vessels of the thorax during the respiratory movements. With the act of inspiration, there is created a difference between the atmospheric and intra-pulmonary pressures to the extent of the force necessary to overcome the elastic resistance of the bronchial and alveolar passages undergoing expansion. At the same time and to the same degree, the extra-pulmonary thoracic structures are also subjected to an equal pressure of a negative kind. This negative pressure when the lungs are at rest (between inspiration and expiration) is, in man, about 5 to 7 mm. of mercury, while at the end of a forcible inspiration it amounts to 30 mm. of mercury. During expiration the conditions are reversed, and at the end of a forcible expiration the vessels in the thorax are subjected to a positive pressure at times so great as to interfere with the free flow of the blood to the heart. The result of these variations is that during forcible inspiration the negative pressure on the thoracic vessels and on the lungs is diminished and there is a free flow of blood to the thorax; the flow to the right heart is increased and the vessels of the lungs become distended with blood. A forcible expiration, on the other hand, exerts a pumping influence on the lungs and the blood is driven on to the left heart, although at times the extra-pulmonary pressure, during forced expiration, may be so great as

to give rise temporarily to a partial venous obstruction in the vessels entering both sides of the heart. In a condition of asphyxia by suffocation there is a marked increase in the variations of intra-thoracic pressure; for if, when the chest forcibly expands, there is no entrance of air, there must be an enormous relative increase of negative pressure in the thorax, determining a great engorgement of the lungs and thoracic veins. Immediately following this engorgement there is a violent expiration, the result of which is to convert the extra-pulmonary negative pressure into a positive pressure on the great vessels. This extra-pulmonary positive pressure of expiration exerted on the pulmonary veins retards the onward flow, and the blood pressure in the vessels in the lungs is raised enormously, the blood being "trapped" between the expulsive force of violent expiration on the one side and a positive extra-pulmonary pressure together with an engorged left heart on the other.

(2) *Effects on the Vaso-motor Centre.*—The vaso-motor centre is extremely sensitive to the influence of carbonic acid, and during asphyxia the effects of the venosity of the blood on the cardio-inhibitory centre are very pronounced. These effects have been studied in animals in which the complication through interference of the convulsive movements have been eliminated by means of urari. It has been demonstrated that in asphyxia (under urari) there is (1) an increase of systemic blood pressure, due mainly to vaso-constriction in the splanchnic area; and (2) an increase in pulmonary resistance and an increase in pulmonary blood pressure. These effects are seen only in the earlier stages of asphyxia, the blood pressure soon becoming lowered through failure of the heart.

These then are the main factors concerned in the great disturbance which ensues in the circulatory and respiratory systems in asphyxia, and their results are manifested in some interesting ways in the following cases.

While the effects produced are the same in kind, they differ considerably in degree, and the cases are considered separately according to the extent of the damage produced on the lung substance.

Cases 1, 2, 3, 4.—These cases, aged six months, ten months, thirteen months, and eighteen months respectively, died as the result of overlying. The changes found on post-mortem examination were those generally associated with the condition of asphyxia by suffocation. On opening the thoracic cavity the lungs were found in a state of moderate distension. There was some degree of sub-pleural ecchymosis, but no extensive hæmorrhage could be detected on naked eye examination. Relative to age the lungs were of normal weight, were crepitant, and floated in water; they were fixed in formalin, and dissection in spirit showed great dilatation of the blood-vessels and small clots of blood in some of the bronchi.

Microscopic Examination.—On microscopic examination the most marked feature is the great dilatation of capillaries and veins, and specially marked is the engorgement of vessels in the interlobular spaces. There is evidence at various parts of slight hæmorrhage under the pleura. Some of the bronchi are in a collapsed condition and contain small quantities of blood in their lumina (fig. 1). An almost constant feature is great dilatation of peribronchial capillaries. At some parts the pulmonary capillaries in the parenchyma are greatly dilated, and in the neighbourhood of these

FIG. 1.—Transverse section of bronchus in asphyxia. Bronchus collapsed, and blood in lumen and peribronchial capillaries dilated. Stain—hæmatoxylin, eosin, and orange. × 45.

dilated vessels there are occasionally small quantities of extravasated blood. At no part is there seen extravasation of blood or air into the interlobular spaces: and no collapse of the alveolar substance of the lung is detected.

Case 5.—This case is that of a child born at six o'clock in the evening and found dead four hours later. He was a strong, healthy-looking infant, breathed freely and with apparent comfort, and presented nothing abnormal on physical examination. Death was due to overlying.

Post-mortem Examination.—The parietal and visceral layers of the pleura were in apposition and the lungs were moderately distended. The right lung weighed 450 grains and the left 375 grains, and they floated readily in water. The most striking feature was an apparent infiltration of

air between the lobules; the intersecting planes between the lobules instead of being almost imperceptibly thin, are at some parts 2 mm. in width. At some places the interlobular spaces were marked by a transparent band, and at others by a row of small transparent beads of visceral pleura. At some parts the individual lobules were even isolated by the dissecting extravasations of air. These changes were most marked on the surfaces of the anterior borders of the lungs, but the intersecting bands of air could be traced deep into the lung substance, although as the root of the lung was

FIG. 2.—Enormously dilated blood-vessel in interlobular space in lung in asphyxia. Stain—hæmatoxylin, eosin, and orange. × 45.

approached the spaces become narrowed. The infiltration did not appear to have passed the roots of the lungs, no air being detected in the tissues of the posterior mediastinum. After fixation in formalin, dissection in spirit showed the foregoing conditions very clearly. The vessels in the interlobular spaces were distended and stripped from the surrounding connective tissue, and were surrounded by the free air which intersected the lobules. At no point was there evidence of free blood in the interlobular spaces.

Microscopic Examination.—As in the previous four cases attention is at once drawn to the enormous dilatation of the vessels, especially of the veins in the interlobular spaces (fig. 2). The sub-pleural capillaries are also engorged as are those round the bronchi. In some parts there is

marked distension of the capillaries in the parenchyma. There is great extravasation of air into the interlobular spaces (fig. 3).

Neither in the interlobular spaces nor in the bronchi is free blood detected, although minute extravasations into the alveoli are seen in the neighbourhood of distended pulmonary capillaries. Examination of individual lobules, even those completely surrounded by extravasated air, shows no evidence of tearing or rupture. Collapse is not a marked feature, though present in a slight degree in those lobules surrounded by large

FIG. 3.—Transverse section of lung in asphyxia. Low power—showing lobules surrounded by large vesicles of air and portions of the lobules collapsed. Stain—hæmatoxylin, eosin, and orange. × 12.

quantities of air (fig. 3). Examination of the elastic tissue by Weigert's method shows no abnormality in quality or amount.

Case 6.—This case is that of a baby born at seven o'clock and found dead two hours later. At birth the child appeared strong and healthy; the colour was good and breathing was normal. The mother states that two hours after birth she noticed the face turn black and there was a discharge of blood from the mouth and nose. Death occurred immediately. The child was illegitimate.

Post-mortem Examination.—The body was that of a strong, well-developed infant. There was considerable subconjunctival hæmorrhage.

There was free blood in the mouth, throat, and larynx, but examination of these passages showed no evidence of the presence of any foreign body. On opening the chest the lungs were seen to be collapsed, and there was a considerable amount of blood in each pleural cavity (about 6 oz. in the right and 4 oz. in the left). There was no pneumothorax and no air in the posterior mediastinum. The lungs were bathed in blood, which was present in the pleural cavities, and on removal blood was seen to escape in small

FIG. 4.—Transverse section of lung in asphyxia, showing enormous extravasation of blood and its consequences. The interlobular spaces are demarcated by channels of blood and the lobules are collapsed 1, Collapsed lobules; 2, channels of blood surrounding lobules; 3, channel of blood under pleura; 4, air-spaces beneath pleura and in lobules; 5, dilated small vessels surrounded by extravasated blood in interlobular spaces. Stain—hæmatoxylin, eosin, and orange. ×15.

quantities from the bronchi. The lungs had an abnormally red appearance, were heavy and resistant to pressure, and were non-crepitant. Minute transparent beads of air were present all over the surface, but larger and more numerous towards the anterior borders. The sub-pleural vesicles of air were irregular in their distribution, at no part being arranged in rows as in case 5, and there was no demarcation of the lobules by extravasated air. On the other hand the surface of the lungs was practically homogeneous, the outline of the lobules being invisible. The right lung weighed 1040 grains and the left 920 grains; they floated in water. After fixation in formalin

and washing in spirit, dissection showed the lungs to be practically solid on account of extravasated blood. There was general collapse of the lung substance, and the individual lobules were marked off by channels of blood in the interlobular spaces. These channels of blood, easily recognised by the naked eye, were continuous with a similar extravasation beneath the pleura, and it was this sub-pleural extravasation which rendered the lobules invisible on examining the surface of the lungs. In addition to the sub-

Fig. 5.—Transverse section of lung in asphyxia, showing blood extravasation, collapse of lung, and large air-vesicles in interlobular spaces. 1, Collapsed lobules; 2, channels of blood in interlobular spaces; 3, large vesicles of air in interlobular spaces; 4, bronchus; 5, bronchiole containing blood; 6, dilated vessel in interlobular space; 7, extravasated blood surrounding vessel. Stain—hæmatoxylin, eosin, and orange. × 15.

pleural air-vesicles there were air-spaces scattered through the substance of the lungs, these had an irregular distribution, and varied in size up to 6 mm. in diameter.

Microscopic Examination.—The most remarkable feature is the large amount of blood pervading the lung structure. For the most part the blood is present in the interlobular spaces and beneath the pleura. In some parts the individual lobules are isolated by the dissecting channels of blood, which have compressed the lobular structures into a collapsed condition (fig. 4).

The bronchi are in some places surrounded by extravasated blood, and

small quantities of blood are present in some of their lumina. The peribronchial capillaries are generally dilated. The blood, however, seems to be largely confined to the interlobular spaces and the subpleural tissue. At no part is there any evidence to show that the hæmorrhage has occurred from the capillaries of the parenchyma inasmuch as the lobules, though compressed and collapsed by the surrounding blood, show no signs of having been ruptured or torn by the dissecting channels. The air-spaces, already referred to, are seen scattered irregularly through the tissue; they vary in size and are lined by connective and elastic tissue fibres; they are sometimes inside the lobules (fig. 4), but the larger ones are usually in the vicinity of vessels or bronchi or in the interlobular spaces (fig. 5). They would appear to be the result of an accumulation of air particles expressed from the alveolar spaces by the pressure of the blood and subsequent collapse of the lobules. So far as the disorganised condition of the lung admits of examination, the elastic tissue would appear to be normal in quantity and quality.

Summary of Pulmonary Changes.

Cases 1, 2, 3, 4.—Great dilatation of vessels in interlobular spaces; dilatation of capillaries in lobules, round bronchi, and beneath pleura; minute extravasations of blood under pleura, into alveoli, and into bronchi. (Fig. 1.)

Case 5.—Great dilatation of vessels in interlobular spaces; dilatation of capillaries in lobules and round bronchi; extensive extravasation of air into interlobular spaces and beneath pleura. (Figs. 2 and 3.)

Case 6.—Great extravasation of blood into interlobular spaces, beneath pleura, and round large vessels and bronchi; collapse of lobules; extravasated air irregularly distributed in vesicles of varying size. (Figs. 4 and 5.)

These changes have the following points in common:—

(1) There is in every case a decided evidence of great blood pressure, as seen in hæmorrhage and dilatation of vessels.

(2) In every case the evidence of change is most marked in the interlobular spaces. It has already been pointed out that the pulmonary changes in asphyxia depend largely on the mechanical influences of the variations in intra-thoracic pressure. These variations in pressure affect not only the large vessels outside the lungs but every structure outside the air containing vesicles and air-passages. Thus, during a deep inspiration the negative pressure on the thoracic structures outside the lungs is increased, and in the same degree there is an increase of negative pressure in the interlobular spaces. This variation in pressure in the interlobular spaces is a factor common to all cases of asphyxia. An increase in negative pressure in the interlobular spaces has an aspirating effect on the blood in the lobules, and

there is a determination of the blood from the centrally situated pulmonary arterioles in the lobules to the peripheral venules in the interlobular spaces; the distended venules of the pulmonary system in the interlobular spaces is a constant feature of asphyxia.

The cases under consideration present the following points of difference:—

(1) Cases 1, 2, 3, 4 show no marked departure from the normal relations of lung structures.

(2) Cases 5 and 6 present marked evidence of great disturbance of lung structures.

The problem which a review of these differences suggests is this—What are the factors which determine such variations in the nature of the lesions produced?

The following conditions may have influenced the results:—

1. Age.
2. Completeness of obstruction.
3. Period in respiratory cycle at which obstruction took place.

1. *Age.*—It has already been noted that, in the case of animals, age is an important factor in determining the length of time occupied in the process of asphyxiation. A full-grown dog usually dies after immersion for 1½ minutes, while a puppy may survive 50 minutes' immersion. This prolonged survival on part of newly-born animals may be accounted for on the supposition that, as yet, the respiratory metabolism in the tissues is comparatively inactive and there is a small demand on the oxygen stored in the blood for carrying on the work of the organism. If there be any grounds for such an explanation in the case of prolonged survival in immersion, the same reasons would account for a prolonged continuation of the nervous and circulatory activities in asphyxiation of an infant. A child of a year would in all probability die sooner than a newly-born baby, inasmuch as the heart and respiratory centre depending more on active metabolic processes would sooner succumb to the poisonous effects of the venous blood. Applying these principles to the cases under consideration, it is seen that cases 5 and 6 are newly-born babies and that in them the pulmonary lesions are extensive compared with those in the older children —cases 1, 2, 3, and 4; and it is quite possible that in cases 5 and 6 the prolonged physiological activity under conditions of deficient arterialisation gave rise to a prolonged strain on the pulmonary structures, sufficient to account in some degree at least for the extent of the lesion; while in the older children the venosity of the blood probably conduced to nervous and cardiac failure before the abnormal activities of the organism had time to cause great derangement of the lung structure.

An important factor in the determination of these differences must be the patency of the foramen ovale; it may be looked on as performing a function similar to that of the patent ductus arteriosus in certain amphibians, whereby prolonged immersion is rendered possible, and there is a temporary suspension of pulmonary activities while the blood-flow is maintained through the patent ductus and the nutrition of the organism is maintained. In the infants the blood-flow would be continued through the patent foramen ovale, and the nourishment of the higher centres maintained, while the lungs were being subjected to the violence of the chest movements of asphyxia.

Another important consideration relative to the effect of age is this, that in the case of the newly-born babies the lungs had only just become accommodated to the new conditions; and the extraordinary violence of the circulatory and respiratory disturbance would be certain to have a more deleterious effect on the recently expanded lungs and pulmonary vessels of a newly-born baby than on those of a child of a year, whose lungs had by that time become accustomed to the demands of the organism.

2. *Completeness of Obstruction.*—The symptoms and changes occurring in dyspnœa and asphyxia differ in degree rather than in kind; consequently, if in the process of asphyxia the obstruction be not complete, the changes will more resemble those of dyspnœa. In a case of incomplete obstruction the intra-thoracic structures are not subjected to such variations in pressure and the heart is better able to cope with the mechanical difficulties it has to meet; in such cases the heart and lungs may be able to accommodate themselves to the new difficulties without dislocation of the lung structure, until such time as the explosive forces of the respiratory centre have been spent or the heart succumbs to venous poisoning. If, on the other hand, obstruction be sudden and complete, the variations in intra-thoracic pressure are very much greater, and the intra-thoracic structures are subjected to the violence of these variations before the nervous centres have had time to become exhausted or the heart has had time to fail. Viewed in the light of these considerations, one would expect that asphyxia was more sudden and complete in cases 5 and 6 than in cases 1, 2, 3, or 4; this conclusion is supported by the fact that in cases 5 and 6 there was strong suspicion of violence.

3. *Period in Respiratory Cycle at which Obstruction took place.*—This consideration applies only to those cases in which the obstruction has been sudden and complete.

(1) If obstruction takes place towards the end of inspiration, the result is as follows:—The lungs are distended with air when the symptoms of asphyxia begin; there will probably be an expansion beyond that at time

of obstruction; the intra-thoracic pressure will be greatly reduced in the mediastina and in the interlobular spaces, and following this there will be an engorgement of the veins in these situations; then comes a violent expiratory spasm. The air in the alveoli is raised to an enormous pressure, putting a great strain on the periphery of the lobule, already affected by the distension of the veins in the interlobular spaces; the air is forced into the interlobular spaces where the pressure is negative, and it intersects its way between the lobules and beneath the pleura. This was probably the condition of affairs in case 5.

(2) If obstruction takes place towards the end of expiration, the result is as follows:—The lungs are in a condition of collapse when the symptoms of asphyxia begin; there will then probably be a prolonged inspiration, the result of which will be to produce a very high negative pressure in the mediastina and in the interlobular spaces: this negative pressure will be considerably greater than that produced in a case where obstruction takes place at the end of an inspiration. Following this inspiration there will be a great flow of blood to the thorax, the vessels becoming engorged and especially the veins in the interlobular spaces. A violent expiratory spasm acting on the lungs in their engorged condition will probably give rise to rupture of the venules and an extravasation of blood in the interlobular spaces, the rupture being the result of an enormous venous pressure exerted on the blood, "trapped" between the force of expiratory spasm and the heart unable to cope with the supply, together with the retarding influence of the pressure in the mediastina, which, by this time, has become positive. This was probably the condition of affairs in case 6.

(3) If obstruction takes place when the lungs are neither distended nor collapsed, there will be a relative modification of the forces which constitute the mechanical influences just referred to. The intra-alveolar pressure cannot be so great as in those cases where obstruction takes place at the end of inspiration, and the interlobular negative pressure cannot be so great as in those cases where obstruction occurs at the end of expiration. This modification of the mechanical influences no doubt in some cases admits of an accommodation on part of the heart and lungs until such time as the nervous and circulatory systems have become exhausted by the poisonous effects of the blood. In these considerations may be found an explanation of the slight degree of disturbance of pulmonary structure found in some cases of asphyxia.

With reference to cases 5 and 6, it has been assumed that the commencement of the extravasation of air and blood depends on and is coincident with the violent spasm of expiration. Whether or not this assumption be correct, the whole lesion cannot be said to be the result of one

expiratory effort. Once the rupture has taken place, there is a rush of air or blood into the interlobular spaces, its progress depending on the suction action of inspiration and the pumping action of expiration, and the whole process lasting only during a few respiratory efforts after the initial rupture. That considerable hæmorrhage may be the result of lowered pressure is evidenced by its occurrence in the perilobular spaces in a lobular consolidation, and it is possible that in asphyxia the interlobular venules may rupture from the lack of support incident to the lowered pressure of deep inspiration. In any case, the possibility of extravasation having commenced during inspiration in no way minimises the importance of the view that the nature of the lesion depends greatly on the period in the respiratory cycle at which obstruction takes place.

I have to express my indebtedness to Dr Galt, medico-legal officer, Glasgow; to Dr Riddell, late house surgeon, Glasgow Maternity Hospital; and to Dr Alexander Mathieson, Oakbank Hospital, Glasgow, for permission to examine and make use of cases occurring in their practice.

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ON THE DEVELOPMENT OF THE HIND-BRAIN OF THE PIG.

By O. Charnock Bradley, M.B., D.Sc., F.R.S.E., *Royal Veterinary College, Edinburgh.* (Plates XIX.–XXIV.)[1]

Part II.

The Rhombic Lip.

In 1886, His (13) called attention to a folding over of the dorsal edge of the alar lamina which he named the "Rautenlippe," and to which he attached great importance as a factor in the development of certain portions of the medulla, and especially of the cerebellum of Man. He stated that the rhombic lip begins to form, in the human embryo, at the beginning of the fifth week, and that it extends from the cervical flexure to the isthmus rhombencephali; in some places being larger, in others smaller.

Since the publication of His' paper several observers, working on the development of the hind-brain of different mammals, have arrived at diverse conclusions as to the formation and significance of the rhombic lip. Herrick (14) figures it as of extensive development in the guinea-pig, and dilates upon its high position as an agent in the formation of the cerebellum.

Dexter (15), on the other hand, avers that in the rabbit there is no trace of it. Kuithan (16) also, after following the development of the cerebellum in the sheep, expresses himself as doubtful of the occurrence of a lip.

Blake (12), in 1900, claimed that it is present in several mammals (pig, sheep, cat, and rat), and gave an illustration of a transverse section through the hind-brain of an embryo rat (3 mm. long) which certainly closely resembled some of the figures given by His. Blake stated that "hitherto it has not been demonstrated in the lower mammalia," and suggested that this omission may be due to the fact that "it is probably extremely transitory in an unfused condition."

Grönberg (6), writing still more recently, and basing his statement on the examination of Erinaceus embryos, speaks in no uncertain voice against the occurrence of a rhombic lip. Not only does he deny its

[1] Figs. 1 to 44 accompany Part I. of this paper, which was published in the last number of the *Journal* (Oct. 1905).

presence in hedgehog embryos, but he even seriously questions its formation in Man.

So far as Man is concerned, the occurrence of a rhombic lip may be assumed to be proved. In regard to its presence in the embryonic brain of the lower mammals, there is not yet sufficient evidence to prove that it is universal or even common. For this reason considerable attention has been paid to the condition of the dorsal border of the alar lamina in the hind-brain of the various pig embryos employed in this research.

In the youngest embryo the edge of the alar lamina passes in a simple manner into the membranous roof of the ventricle. No indication of an outward folding is to be observed in any part of the rhombencephalon of the 19 and 22 days embryos. In the next older embryo (15 mm.) there is a considerable difference. In the most posterior part of the medulla the upper border of the alar lamina is no longer thin, but has become thick and rounded, forming an apparent equivalent to His' "Flügelwulst," along the lateral border of which the membranous roof of the ventricle is attached (fig. 12). When sections are followed forwards it is found that not only is the border of the lamina rounded, but there is also the appearance of an outward bending; that is to say, there is distinct evidence of the formation of a rhombic lip with a well-marked outer and a shallow inner "Lippenfurche." This is well seen opposite the otic vesicle. Towards the anterior limit of the vesicle the folding-over almost entirely disappears, to be again well developed as soon as the vesicle is completely passed. On a level with the origin of the root-complex of the N. acustico-facialis there is a slight diminution in the size of the lip—a diminution doubtless associated with the exit and entrance of nerve-fibres at this point (fig. 13). Immediately in front of this root the lip assumes its maximum development, both its outer and inner "Lippenfurchen" being deep (fig. 14). The root of the N. trigeminus is connected with another diminution in the size of the lip, which is once more clearly marked externally in the region of the lateral recess; the outer "Lippenfurche" being continued slightly beyond the anterior limit of the recess (fig. 5).

The various neuromeral grooves cross the "Flügelwulst," so causing the production of a number of rounded eminences.

With certain reservations it may be said that, so far as concerns the rhombic lip, sections through the hind-brain of this embryo bear a marked resemblance to the figures given by His of a five-weeks' human embryo. There is, however, none of that flattening of the medulla at the widest part of the ventricle, so conspicuously present in Man. There is, further, as has been previously stated, no clear distinction of alar and basal laminæ in the widest part of the medulla.

It is not possible to follow the rhombic lip for even the shortest distance on to the cerebellum at this stage.

A considerable advance has been made in the growth of the lip between the 15 mm. and the 23 mm. stages. In a 23-mm. embryo it is again poorly developed in the posterior part of the medulla, and fusion is apparently taking place between it and the wall of the brain-tube (fig. 16). Opposite the anterior part of the otic vesicle it would be difficult to say that a rhombic lip had ever existed were it not for the evidence afforded by the younger embryo. In connection with the lateral recess, on the contrary, the lip has grown considerably and now forms a substantial floor to the recess (fig. 18). This region obviously corresponds to the district in which the lip was greatest in the 15-mm. embryo.

At this stage there are unmistakable traces of a folding of the edge of the cerebellar lamina; but in no part is it so well marked as was formerly the case in the medulla (fig. 19). A cerebellar rhombic lip can be detected in both transverse and sagittal sections; the latter showing it best in the region of the lateral recess. As sagittal sections are followed towards the middle line the lip becomes gradually less and less, but does not entirely disappear until the median plane is closely approached.

In the posterior part of the medulla of a 25-mm. embryo there is a thickened hem appended to the border of the former alar lamina, and to it the membranous roof of the ventricle is attached. The hem is sharply marked off from the rest of the wall of the ventricle by an internal furrow, above which is a rounded ridge-like prominence (figs. 21 and 22). The furrow began to appear in the 23-mm. embryo (*cf.* fig. 16), and it does not seem altogether unreasonable to compare it with a groove figured by His (fig. 13 (13)) as being present in a five-weeks' human embryo internal to the "Flügelwulste." If such a comparison be allowed, then the rounded ridge above the furrow must be the remains of the "Flügelwulste." However this may be, the hem itself may be considered the representative of the rhombic lip, Blake having shown that in the lower mammals it has such an appearance.

In connection with the lateral recess the rhombic lip continues to grow both in thickness and also in an outward direction (fig. 23). Attention has already been called by Blake to the important rôle played by the lip in the formation of the recess, and the material at present described lends support to his statement. It should be added that the N. acustico-facialis has established a close connection with the ventral wall of the recess so formed.

There is still a slight trace of a rhombic lip in connection with the cerebellum in the 25-mm. embryo, but this is the latest stage in which it can be detected.

As has been previously stated, the most posterior part of the medulla has become "closed" in the 32-mm. embryo; the "closed" portion being provided with a dorsal median furrow. Just before the central canal enters into the ventricle a ridge makes its appearance in this furrow (fig. 24). If it be followed forwards it is found that the ridge is continuous with rhombic lips such as were described as occurring in the 25-mm. embryo (figs. 25 *et seq.*); that is to say, the closure of the medulla has been caused by the fusion of the lips of the two sides. From this point the rhombic lip can be easily followed forwards—being found to present an appearance not unlike that of the next younger specimen, and gradually increasing in size as the entrance to the lateral recess is approached (figs. 28 and 29).

A slight exaggeration in the thickness of the lip is shown in fig. 29. This follows upon a narrowing of the roof of the ventricle just behind the opening into the lateral recess, which causes the lip to incline inwards and forwards. Sections of it, therefore, are cut somewhat obliquely. The obliquity of section, however, does not account for more than a comparatively small part of the width of the lip as illustrated.

That part of the rhombic lip which is associated with the lateral recess has increased in thickness as well as in lateral dimensions. Consequent upon the addition to its width, the lip is now folded farther over the side of the medulla; but there is still no very remarkable degree of fusion between the medulla and the lip. The independence of the two structures is well shown in fig. 29. Fig. 29 also demonstrates that the lateral recess is growing backwards beyond the level of the aperture of communication with the body of the ventricle, and that the N. acustico-facialis is now closely associated with the rhombic lip.

The "closed" part of the medulla has increased in length in the 52-mm. embryo. As in the younger specimen, it possesses a dorsal median fissure. And, again, before the central canal opens out into the fourth ventricle a low rounded ridge appears in the fissure, thus materially reducing its depth (fig. 32).

In transverse sections there is an area of tissue, differing structurally from that adjacent to it, stretching from the surface of the medulla down to the central canal, and corresponding in lateral extent to the width of the ridge in the bottom of the dorsal fissure (fig. 32). It has evidently been produced by the fusion of the two rhombic lips, for the examination of serial sections shows a continuation of the area with lips such as were present in the 32-mm. embryo (figs. 32 and 33).

The disposition of the epithelium over the rhombic lip in the neighbourhood of the posterior end of the ventricle is noteworthy. Immediately upon the opening up of the central canal to form the ventricle, *i.e.* as soon

as the area of union of the two rhombic lips is passed, the epithelium, though of the same thickness over the greater part of the wall of the ventricle as in the central canal, becomes remarkably thin over the lips themselves (figs. 33, 34, and 35). This peculiarity is retained for some distance forwards; but more anteriorly the lip carries as thick an epithelium as the rest of the interior of the ventricle.

Just as the opening into the lateral recess is being reached, there is, as previously, a conspicuous increase in the size of the rhombic lip (fig. 41) —a condition, however, not demonstrable in older embryos. That part of the lip which assists in bounding the recess is beginning to lose its hitherto remarkable independence.

The appearance presented by the central canal in an 80-mm. embryo is possibly of interest. About the junction of the spinal cord and the medulla the canal is of fair width, and, judging from the arrangement of its epithelium, is undergoing constriction by fusion of its walls both dorsally and ventrally. If the canal be followed forwards, it is first observed to narrow; and then its lateral walls *appear* to fuse about their middle, thus producing the appearance of two canals—a dorsal and a ventral. Into the dorsal canal projects a slight dorsal ridge of epithelium. Still farther forwards the dorsal canal enlarges—the ridge of epithelium being still present—and finally appears to form the single central canal which opens into the ventricle Though this is the appearance presented by sections, it is very doubtful if there is even an attempt at fusion of the lateral walls of the canal. Some sections which had doubtless been rather more roughly handled in preparation show the walls separated from each other by a very narrow chink.

This condition of the central canal of the medulla would not have been so fully described were it not that Balfour (17) was originally of opinion that diminution in the size of the central canal of the spinal cord was produced by a median coalescence of its walls. It was thought that here might possibly be an appearance similar to that which led Balfour to his conclusions.

A dorsal median fissure in the "closed" part of the medulla is not present in the 80-mm. embryo. Its place is taken by a triangular area of tissue, scantily provided with nuclei, which represents the opposed and fused rhombic lips (fig. 46). At the apex of the ventricle the lips no longer project from the edge of the medulla; but their extent is determinable as a sparsely nucleated area continuous with the structurally similar field in the "closed" portion of the medulla (fig. 47).

In view of the condition exhibited in the older material, it is well here to call attention to the fact that there is a manifest thickening of the

epithelium about the lower limit of the fused rhombic lips (figs. 47 and 48). Over the major part of the lip the epithelium is almost as thin as was found to be the case in the next younger embryo.

On passing forwards the pale area representing the rhombic lip disappears and the lip forms a projection such as has been seen previously (figs. 49 and 50).

Fusion between the floor of the lateral recess and the medulla still goes on, but there is no difficulty in seeing the line along which it has taken place (fig. 51).

In the embryo 100 mm. in length there is again a trace of a dorsal median fissure in the most posterior part of the medulla (fig. 52). As stated above, this was not to be found in the 80-mm. embryo; it appears possible, therefore, that it is a new formation produced by inequalities in the rate of growth of different parts of the medulla. As the groove runs forwards it becomes obliterated by the presence of a pale triangular area like that previously seen (fig. 53). Careful measurements show that the area increases in both its lateral and vertical dimensions as it is followed forwards. Its continuity with the rhombic lips is as evident as it was in the younger embryo (figs. 53, 54, and 55). Contrary to the condition present in the earlier stages, the bulk of the rhombic lip diminishes as the opening into the lateral recess is approached (figs. 55 and 56).

The character of the central canal, and its modification as it opens into the ventricle in the 100-mm. embryo, seem worthy of note. Some little distance (less than 300μ) before the canal reaches the ventricle it has the form of a moderately wide vertical slit with a median constriction, but none of that approximation of its lateral walls seen in the 80-mm. embryo (fig. 52). (The constriction is greater in a section 140μ farther forwards than the one from which this figure was made.) The constriction produces the appearance of two dilatations in the canal. A little farther forwards the slit is elongated by the occurrence of a third dilatation dorsal in position (fig. 53). Still more anteriorly a cleft sunders the pale area which represents the combined rhombic lips. At the upper edge of the third dilatation and about the lower limit of the rhombic-lip area is a thickened patch of epithelium such as was seen at an earlier stage (fig. 54).

The manner in which the central canal of a 150-mm. embryo comes to an end differs somewhat from the foregoing description. Here the pale triangular area is present on a level at which the canal is still small; that is, the third dilatation mentioned in the preceding paragraph has evidently been obliterated by the coalescence of the dorsal part of the walls of the canal. The area itself is even more obvious than before on account of

its marked vascularity. (Blake has directed attention to the fact that the extent of the fused rhombic lips can be determined by the greater vascularity of the area of tissue so produced.) In addition, the area forms a dorsal projection in transverse sections (figs. 59 and 60). In this specimen the antero-posterior diameter of the area is absolutely less than it was in the 100-mm. embryo. In the latter it measured 252μ from its most posterior recognisable limit to the point of separation of the two rhombic lips; in the 150-mm. embryo it only measures 204μ between similar points. This circumstance indicates a gradual loss by the area of its distinctive histological characters, the structural change occurring first posteriorly and advancing towards the apex of the ventricle. The area clearly forms the obex of the adult brain.

As the central canal is entering the ventricle it shows the constriction noted in the 100-mm. embryo; but the third—most dorsal—dilatation is replaced by a rounded ridge on each side of the canal. This is the funiculus separans of Retzius (fig. 8). The two funiculi blend posteriorly in such a manner that there is a slight backward prolongation of the cavity of the ventricle above them (figs. 8 and 60). The more dorsal of the two dilatations of the central canal is continued into the ventricle as the ala cinerea (fig. 8). The rhombic lip, passing forwards from the obex, forms the area postrema, which gradually becomes smaller and more and more separated from the bulk of the medulla. A little distance behind the opening into the recess it is very small and forms a thin projection: just as the opening is reached it can hardly be said to be present at all.

That the rhombic lip is an important factor in the formation of the tuberculum acusticum has been claimed by Blake. The present research lends support to the claim (figs. 63 and 64).

From what has been said above, it follows that the rhombic lip of the pig differs somewhat from the like structure in Man. From the time of its earliest appearance it is much more perfectly formed in the region of the lateral recess. In the posterior part of the medulla the lip is small in the younger material, but attains a good development later. In the middle district of the medulla there is an imperfect development of the lip during the whole of embryonic life. Immediately behind the opening into the lateral recess it is large enough to be remarkable during the earlier stages covered by the material at present considered; but later this comparative prominence is lost (*cf.* figs. 41 and 56). At no period is the folding over of the lip so great as has been described by His as occurring in the human embryo; there is never even an approach to the condition as depicted in His' fig. 16 (18). It is difficult to imagine that the rhombic lip of the pig forms the olivary body, etc.—at any rate in the manner as related by His;

it seems more probable that the fasciculus solitarius becomes buried as the consequence of migration of neuroblasts independent of the formation of the lip. This would harmonise with the inability of Grönberg and Dexter to find the lip in the hedgehog and rabbit. Further, it cannot be claimed that it plays more than a very small part in the formation of the cerebellum of the pig. The cerebellar rhombic lip appears later than the medullary lip; it is much smaller, does not reach the middle line, and all traces of it are soon lost.

It must be concluded therefore from these observations on the pig, and from the published results of other investigations, that a rhombic lip is not invariably present in mammals, and, when present, is not so important a factor in the development of the medulla as it is in Man. In connection with the cerebellum its morphologic value is small.

The Cerebellum.

Since the earliest observers were of opinion that the hind-brain presented a yawning cleft in its roof during the first stages of its development, it was natural that they should conceive the cerebellum as arising from a pair of lateral Anlagen which, gradually growing towards each other, ultimately fused in the middle line. This view originated, according to Mihalkovics, with Fracassati (19), and was acquiesced in by all subsequent writers up to the time of the appearance of the first edition of Kölliker's Embryology (9). Tiedemann (20), Serres (21), v. Baer (22), Valentin (23), Schmidt (24), and Kollmann (25) were of this opinion.

Kölliker gave pause to the prevailing theory when he described the cerebellum as developing as a thickening of the roof of the most anterior part of the hind-brain—the thickening soon attaining the form of a transverse plate. Mihalkovics (26) followed Kölliker in considering the cerebellum to grow out of a transverse curved "Kleinhirnlamella." Lahousse (1888 (27)) and Hertwig (1893 (28)) are examples of moderns who hold with an unpaired cerebellar Anlage.

Most recent writers, however, describe a pair of lateral Anlagen. Goronowitsch (29) so represents the development in Acipenser, and Schaper (8) believes that the cerebellum of Teleosts springs from a bilaterally symmetrical Anlage.

Stroud (30) doubts whether the cerebellum as a whole grows out of a thickening occurring in the roof of the hind-brain at the constriction of the isthmus. If this transverse plate is the cerebellum, he asks, "Where is the valvula?" He appears to incline to the view that the cerebellum proper develops from a pair of Anlagen which appear posterior to the

thickening, and sums up by saying, "The mammalian cerebellum is developed from the caudal part of the epicœlian roof."

Kuithan (16), from his observations on the sheep, is of the opinion that the embryonic cerebellum has at first an unpaired Anlage, but later it passes through a stage in which paired Anlagen can be detected. Prenant (31) joins the ranks of those who adhere to the opinion that there are originally two lateral structures from which the cerebellum arises; and Grönberg (6) is led to the same conclusion by his examination of hedgehog embryos.

There appears to be sufficient justification for the assertion that the cerebellum of the pig develops from a pair of lateral rudiments. The median connection present in the youngest embryo examined (19 days) is so thin that there appears to be no reason for considering it of more importance than the Deckplatte of the spinal cord. It is merely a connecting-link between the alar laminæ of opposite side of the rhombencephalon. Further, the connection so established is of short sagittal extent only.

The rudiments of the cerebellum which are present in the 19-days embryo are not marked off from the medulla by anything more than the occurrence of a maximum width of the brain tube. The main connection of the two halves of the organ is the thin membranous roof of the ventricle, each half having a border which slopes gradually inwards as it passes forwards. Speaking generally, there is an interval between the two halves of the cerebellum in the form of a moderately elongated isosceles triangle whose base is formed by a line drawn transverse to the long axis of the rhombencephalon on a level with its widest part, and whose apex points forwards.

As development proceeds the superficial area of the two moieties of the cerebellum increases, and their median connection is extended anteroposteriorly from an expansion of their line of contact. The median connection, though gradually becoming thicker, does not do so in proportion to the increase in its sagittal extent; the consequence being that, for a long time, the two halves of the cerebellum are joined to each other by a remarkably thin bridge, internal to which is a longitudinal fissure whose relative depth increases, rather than diminishes, up to a certain stage of development. How this fissure develops into the cerebellar ventricle, and how it is not entirely obliterated even in a 100-mm. embryo, have been related.

Concerning the manner in which the originally thin median portion of the cerebellum increases in thickness, with a concomitant diminution in the depth of the internal longitudinal fissure, there has been some divergence of

opinion. Kuithan inclines to the view that there is an approximation of, and, finally, fusion between the two walls of the fissure. Grönberg, on the other hand, holds that Erinaceus embryos do not exhibit any fusion of the ependyma. Schaper, as the result of his investigations into the development of the cerebellum in teleostean fishes, concludes that the connecting lamina between the two lateral halves does not develop into typical cerebellar tissue.

The question is evidently not one to which a satisfactory answer can be readily found. In the embryo of the pig there is certainly some thickening produced by proliferation of cells within the median part of the cerebellum itself. But there is the possibility that these cells have migrated thither from more lateral areas. It is not without interest to note that a ridge is present, in certain embryos, at the bottom of the internal median fissure of the cerebellum (figs. 30 and 43), not altogether unlike that which appears in the depths of the sulcus centralis of the floor of the ventricle.

The extraordinary uniformity in the architecture of the whole of the hind-brain in the youngest embryo recalls the question as to whether a division of the rhombencephalon into two distinct segments, as originally suggested by v. Baer, is based upon altogether good morphological grounds.

Edinger's assertion that the cerebellum is in the highest probability one of the oldest segments of the brain (32) does not remove the impression, gained from an examination of the literature, that it is fundamentally merely a continuation of the posterior part of the rhombencephalon; or, as Spitzka has expressed it, a dorsal hypertrophy of the hind-brain.

That the cerebellum of the lower animals is mainly, if not entirely commissural has been shown by the researches of Burckhardt (on Protopterus (33)), Osborn (on Cryptobranchus and Amphiuma (34)), Fish (on Desmognathus (35)), Kingsbury (on Necturus (36)), and others. This leads to the deduction that, in its original form, the cerebellum was not an important nerve-centre; its subsequent attainment to a high morphological position being due to an augmentation in volume and an elaboration of structure rendered necessary by physiological specialisation.

The structural continuity of medulla and cerebellum lends support to the hypothesis that they are merely different parts of one and the same brain segment. In 1888, Goronowitsch (29) made the statement that, in Acipenser, the molecular layer of the cerebellum (with cells of Purkinje) is continued over the tuberculum acusticum as a crest, to which he gave the name of "Cerebellarleiste." A like condition has been found to obtain in Amia (Kingsbury (37)), Acipenser rubicundus (Johnston (38)), Mustelus (Houser (39)), and Petromyzon (Johnston (40)). Johnston in particular is very earnest in his insistence upon "the morphological unity of the dorsal

horn, acusticum, and cerebellum": a unity rendering a dividing line between the cerebellum and tuberculum acusticum an impossibility.

The relationship between the acusticum and cerebellum is further shown by the fact that the N. acusticus has an end-station in both. This has been demonstrated by a multiplicity of observations on all classes of vertebrates. Of those to whom we owe knowledge of this fact may be mentioned Mayser (41), Goronowitsch (29), Johnston (38 and 40), Köppen (42), Edinger (43), Sala (44), Brandis (45), and Wallenberg (46). Even in Man himself, in whom the cerebellum has become most highly specialised, the vestibular nerve sends fibres into the cerebellum.

In view of the facts which have been accumulated, and which are still rapidly accumulating, there seems good reason for considering the cerebellum and medulla as part of one segment of the brain, even if we do not go so far as Haller (47) and say that beyond doubt the "Cerebellarleiste" and its associated cerebellum have developed from the outer sensory region of the medulla oblongata—thus reducing the cerebellum to the level of a mere appendage to the medulla. That even the latter and more extreme conclusion is justified by some—not to say many—facts may, however, be readily contended.

The problem being one of much complexity, and further evidence being still needed for its solution, it may be well to suspend judgment and await further developments; concluding with Wilder (48) that there is no reason why we should not go on "entertaining and employing, *as a convenient 'working hypothesis,'*[1] the interpretation made by v. Baer and accepted by the majority of later authorities upon the subject," at the same time remaining alive to the possibility that the division of the rhombencephalon into two segments, though convenient, may not be strictly scientific.

THE FORAMEN OF MAJENDIE.

A figure given by His (fig. 33 (49)) shows the roof of the embryonic fourth ventricle to be of the same thickness throughout. In the process of development a relative thinning takes place, and it seems probable that, in some mammals at least, this continues until an actual break occurs at certain points of the roof, whereby the cavity of the ventricle is placed in communication with the sub-arachnoid space. That such a communication is established in Man and the higher apes, at least, appears to have been proved beyond doubt by careful work recently undertaken. Whether all the apertures found in Man occur with the same regularity in all mammals has not been so clearly demonstrated. The older methods of research were

[1] The italics are not in the original.

not such as lent themselves to proving or disproving the existence of small apertures in so delicate a membrane as that which closes in the fourth ventricle. So long as the only method employed was that of ordinary dissection it was only natural that different observers should arrive at different conclusions, the amount of tension requisite for the production of an artificial opening being so very small. Even when the process of embedding and cutting sections in paraffin or celloidin is used the results may be untrustworthy if there has been any roughness indulged in during the extraction of the brain from the cranium.

The only way in which all danger of producing artifacts can be obviated is by embedding and cutting the whole head—a matter of obvious difficulty in the case of the larger animals. Embryos lend themselves much more readily to this method than do adult animals. But in the case of the use of embryonic material, negative evidence is of greatly less value than positive. If there be no opening in the embryo, it does not follow that there should also be none in the adult: it is easily conceivable that an intercommunication between the ventricle and the sub-arachnoid space may be formed after birth. If, however, an opening is found to be present in the embryo there is a strong probability of its being present in the adult also.

In the early part of last century Burdach (50) described the hinder end of the roof of the fourth ventricle as being perfectly closed. But, in 1842, Majendie (51) pointed out that there is normally and constantly an opening in the roof of the human ventricle; this foramen being bounded by the choroid plexus and the posterior medullary velum, and its size differing very much in different individuals.

Since 1842 conflicting opinions have been expressed as to whether the foramen of Majendie is an entity or a chimera. Virchow (52) denied the existence of any connection between the ventricle and the sub-arachnoid space. Luschka (53) succeeded in finding an opening in the tela choroidea inferior of Man, but added that in many animals the ventricle is closed. In 1861, Reichert (54) averred that the foramen is only produced during the process of removal and manipulation of the brain; whereas, in the same year, Kollmann (25) not only described the opening as being natural, but also stated in what manner it is bounded.

Quincke (55) saw in the foramen a very variable and not always demonstrable opening in the connective tissue of the roof of the ventricle, Key and Retzius (56) examined 100 human brains and found a foramen of Majendie in 98 of them. Sée (57) declared himself on the side of those who denied the existence of the foramen, and stated reasons for his attitude. It is exceedingly easy, he said, to tear the fine membranous roof of the ventricle during the removal of the brain; in several animals, *e.g.* horse,

goat, etc., it has been shown that the ventricle is closed, and the overfilling and distension of the ventricle, as the consequence of pathological processes, is not reconcilable with the acceptance of the presence of an opening. Kölliker (9) held that there is complete closure of the ventricle in the embryo, and that this is the rule in the adult also. The foramen of Majendie, when present, he said, is no regular structure.

In 1885 the problem was attacked by Hess (58). He examined the brain of thirty adult human beings, ten new-born children, and seven embryos of different ages. In only one instance did he fail to find an opening. He came to the conclusion, therefore, that the foramen is constant in man. He thought that it is possible that there is always an opening in the roof of the embryonic ventricle, since at five months the aperture is wide. He also found a foramen in the embryo of the cat.

Later observations by Wilder (59), Morton (60), Jacobi (61), Kohlmann (62), and others appear to indicate that the foramen as described by Majendie is a natural opening in Man at least. Cannieu (63) is not so sure of the presence of a natural and normal opening in the lower animals.

The subject has received very careful attention at the hands of Blake (12), whose results were published in 1900. He describes a protrusion of the roof of the ventricle in the form of a glove-finger-like projection, which remains closed in the majority of mammals but becomes an opening in Man and the anthropoid apes.

In the pig there is little that is remarkable in the changes which occur in the roof of the ventricle before the embryo has attained a length of 50 mm. The only point which needs mention is the relative thickness of the roof in different regions. In all the younger embryos (except that of 19 days) an oval patch of the membranous roof differs from the rest in being noticeably much thinner. This occurs about the centre of the "Rautenfeld," and can be distinguished as early as the twenty-second day. It is not due to a reduction in the number of the layers of cells forming the membrane but rather to a flattening of the individual cells; for the zone immediately surrounding the patch is provided with no more than one layer of cells, thus agreeing in constitution with the patch itself.

Transverse sections through the "closed" part of the medulla of an 80-mm. embryo show a backward extension of the cavity of the ventricle into a membranous cul-de-sac which lies on the dorsal surface of the medulla. At this stage the cul-de-sac is closely applied to the medulla, to which it is adherent; its extent, in a sagittal direction partly and in a lateral direction entirely, corresponds to a triangular area formed by the coalesced rhombic lips (fig. 46). A younger embryo (52 mm.) shows the commencement of the condition. It is evident that, as the rhombic

lips fuse together, there is not a corresponding diminution in the antero-posterior diameter of the roof of the ventricle; the "closed" medulla rather, in a sense, burrowing under the roof and so causing a cul-de-sac.

The backward continuation of the cavity of the ventricle is very definite in a 100-mm. embryo. Its form may be well likened to that of a finger of a glove. It extends farther back than the caudal limit of the area produced by the fusion of the rhombic lips, and it is now free, its caudal extremity being some distance removed from the surface of the medulla (fig. 52).

A 150-mm. embryo shows the same kind of protrusion, but much better developed. It now extends backwards almost to a level with the most caudal part of the cerebellum, and is, posteriorly, in even closer relation with the cerebellum than with the medulla. Although the walls of this caudal protrusion are thin, there is no indication of a foramen of Majendie.

The embryo of the pig, therefore, corroborates the statement made by Blake. And, it may be added, a careful examination of the adult brain leads one to assert that the protrusion never becomes an opening.

Openings in the Lateral Recesses.

Although Bockdalek (64), in 1849, stated that the choroid plexus lies free under the arachnoid mater in the region of the "Fullhorn," the description he gave was not such as to cause modern morphologists to associate his name with the opening in the lateral recess of the fourth ventricle.

Luschka (53), some years after the publication of Bockdalek's paper, described the outer angle of the ventricle as standing in connection with the sub-arachnoid space, and the lateral part of the choroid plexus as lying free under the arachnoid. This, however, was not supported by Reichert (54), who, after a minute description of the choroid plexus, concluded with the declaration that there is a membranous closure of the lateral recess of the ventricle.

There seems little doubt that to Key and Retzius (56) should be given the credit of having provided the first clear and detailed description of the connection of the cavity of the ventricle with the sub-arachnoid space through the intermediation of an aperture in the lateral angle of the ventricle. Out of 100 human brains examined by them the communication was found in all but three.

Kölliker (9) expressed himself as convinced that the openings are even less of regular structures than the foramen of Majendie, which, as previously mentioned, he held to be usually absent. Hess (58) concluded that the apertures are constant in man. Bland Sutton (65) attached great im-

portance to the openings, and stated it as his opinion that their complete absence, or their closure before or after birth, leads to pathological results.

Morton (60) and Jacobi (61) have averred that the openings are normal and always present, whereas Cannieu (63) casts doubt on their natural occurrence in the lower animals.

Blake (12) included the considerations of these openings in the paper to which reference has already been made. The results of his investigations are of great interest, since they indicate that the openings are always present in mammals, and are even larger in the lower animals than in Man. It would appear that there is a kind of compensatory development. When the foramen of Majendie is absent the openings in the lateral recesses are larger than when the foramen is present.

The first rudiments of lateral recesses occur in the 15-mm. embryo of the pig, *i.e.* in the same specimen in which a rhombic lip is first observed. From this stage onwards the recess is bounded ventrally by the rhombic lip. Its caudal boundary is very indefinite in the 15-mm. embryo, but in the next older specimen (23 mm.) this limit is clearly formed, for now the recess has a greater antero-posterior diameter than has the opening from it into the body of the ventricle. It extends farther back, as well as farther forward, than the level of the bounds of the opening into it; there has been, therefore, a bulging backwards of the caudal wall of the recess. The disparity between the antero-posterior measurements of the recess and of its opening into the ventricle becomes exaggerated as development proceeds.

As early as the 23-mm. stage the choroid plexus has invaded the recess (fig. 18). In the 25-mm. embryo, that part of the plexus which invaginates the outer wall of the recess is more anterior in position than the portion of it which belongs to the ventricle itself. Later, the median part of the plexus grows at a greater rate than the lateral portion.

A very important process begins in the 80-mm. embryo. The most posterior part of the recess in this specimen has very attenuated walls, consisting solely of very thin epithelium, which, over blood-vessels especially, can scarcely be said to be perfectly continuous (fig. 50). There is, however, as yet no definite discontinuity of the epithelium. The rest of the wall of the recess is composed of thick nervous tissue except along the line of invagination produced by the choroid plexus (fig. 51).

In the 100-mm. embryo there is a wide area in the most posterior part of the posterior end of the recess from which the epithelium has entirely disappeared. In fig. 56 the termination of the epithelium is shown to occur abruptly, the contour of the recess remaining imperfectly preserved by loose and delicate connective tissue. In some sections from the same

embryo this tissue is more scanty and interrupted than in the one from which the figure was made.

The break in the wall of the recess is complete in the 150-mm. embryo (fig. 63), and the communication between the cavity of the ventricle and the sub-arachnoid space is fully established. Sections taken farther back than the one illustrated in the figure show the choroid plexus lying free in the sub-arachnoid space at some distance posterior to the caudal end of the recess. It seems worthy of note that the break in the wall does not occur along the line of invagination of the choroid plexus. Both fig. 56 (100-mm. embryo) and fig. 63 (150-mm. embryo) show that the opening has been produced by a thinning of the lower part of the outer wall of the recess.

The embryo of the pig, then, lends confirmation to the statement as made by Blake that, while the foramen of Majendie is wanting in the lower animals, openings of large size exist in the lateral recesses.

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EXPLANATION OF FIGURES.[1]

The outlines of all the figures representing sections were made by means of a Leitz camera lucida.

The figures illustrating sections are arranged so that the first figure belonging to one particular embryo represents the most posterior section; the last figure of the series representing the most anterior.

The following reference lettering is common to all the figures:—

a.c.	ala cinerea.
a.l.	alar lamina.
a.m.v.	anterior medullary velum.
a.p.	area postrema.
b.	backward projection of the roof of the fourth ventricle.
b.l.	basal lamina.
bl.vs.	blood-vessels.
cb.	cerebellum.
c.c.	central canal.
c.v.	cerebellar ventricle.
ch.pl.	choroid plexus.
d.m.	dura mater.
floc.	flocculus.
f.s.	fasciculus solitarius.
f.sp.	funiculus separans.
fw.	Flügelwulst.
h.b.	hind-brain.
l.r.	lateral recess.
m.b.	mid-brain.
nX. etc.	nucleus of X etc. cranial nerve.
ob.	obex.
o.v.	otic vesicle.
pfl.	paraflocculus.
p.m.v.	posterior medullary velum.
r.l.	rhombic lip.
s-a.s.	subarachnoid space.
1, 2, 3, *etc*	1st, 2nd, 3rd, etc., neuromeral grooves.
V. etc.	V. etc. cranial nerves.

Figs. 47–51. 80 mm. embryo. Transverse sections through the hind-brain. Fig. 50 passes through the posterior part of the lateral recess.

Figs. 52–58. 100 mm. embryo. Transverse sections through the hind-brain. Figs. 53–55 illustrate the rhombic lip. Figs 56 and 57 pass through the lateral recess. Fig. 58 shows the cerebellar ventricle.

Figs. 59–64. 150 mm. embryo. Transverse sections through the hind-brain. Figs. 59–62 illustrate the rhombic lip. Figs. 63 and 64 pass through the lateral recess.

[1] The cost of reproduction of the figures has been defrayed by the Carnegie Trust for the Universities of Scotland.

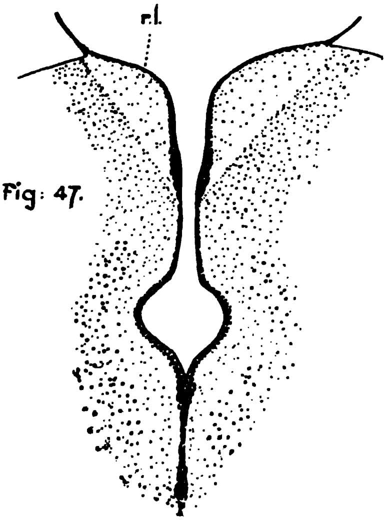

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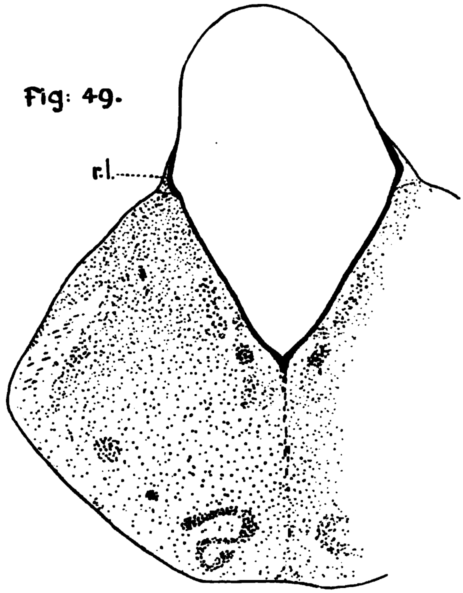
Fig: 49.



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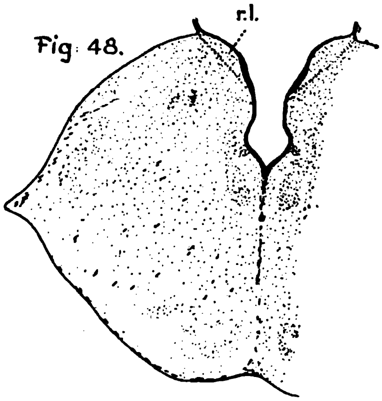

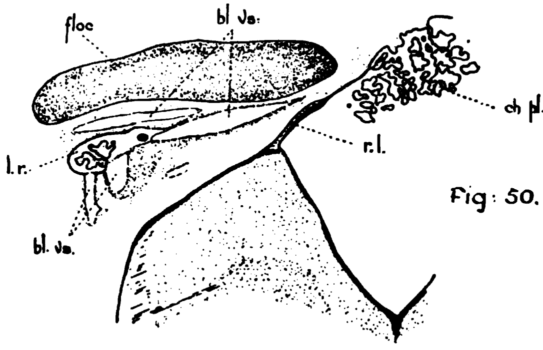

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Fig. 52.

Fig. 54.

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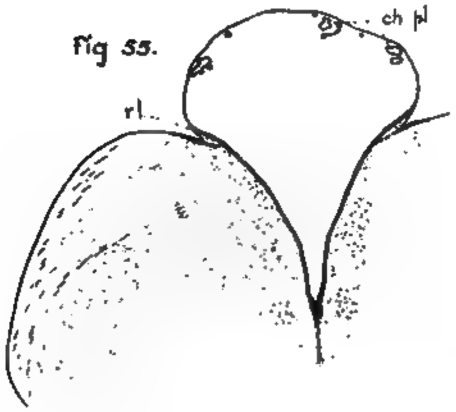

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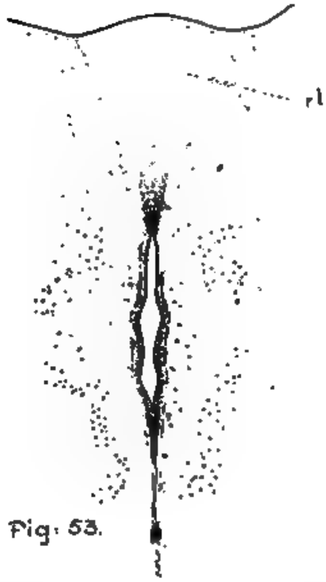

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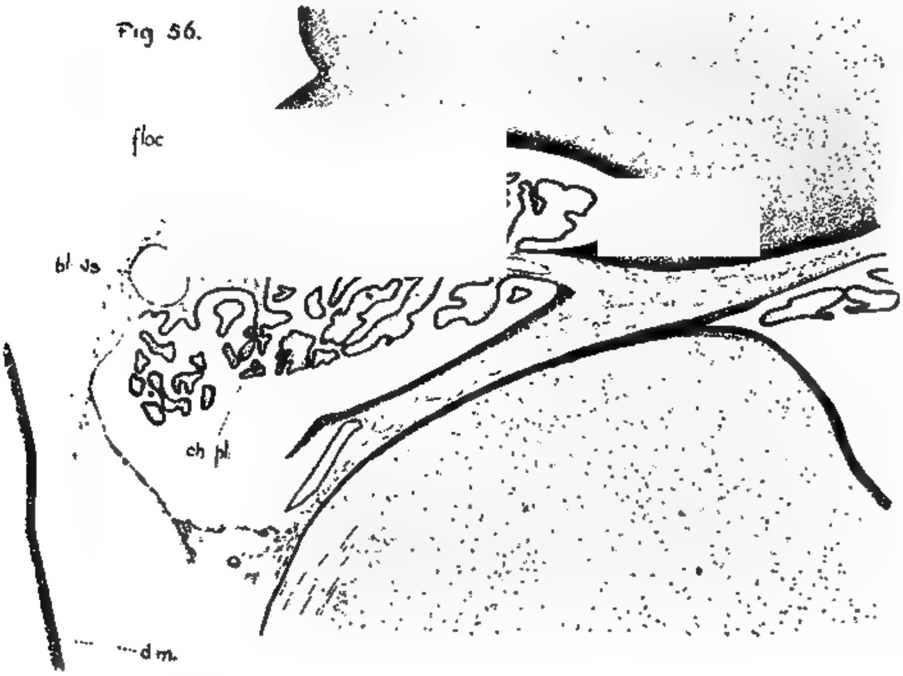

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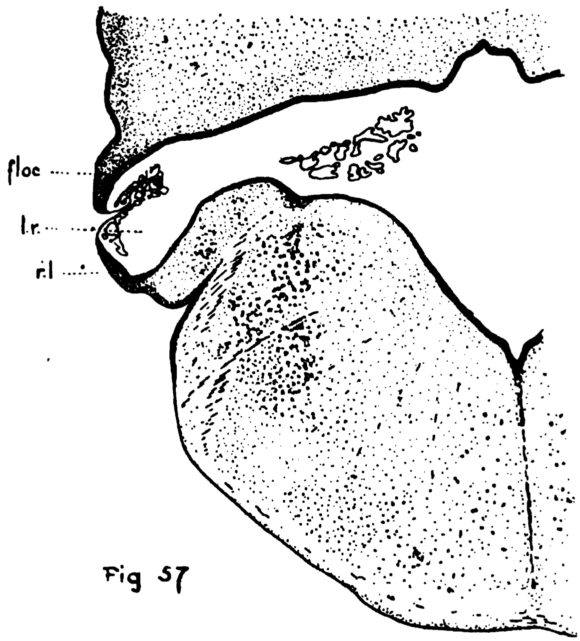

Fig 57

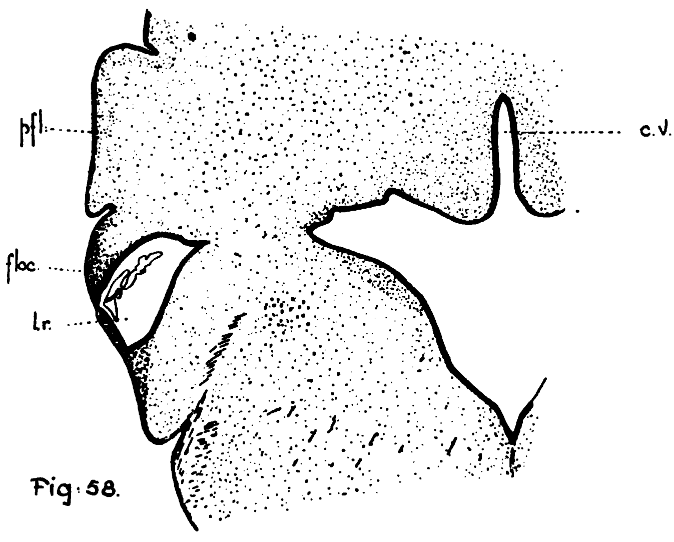

Fig. 58.

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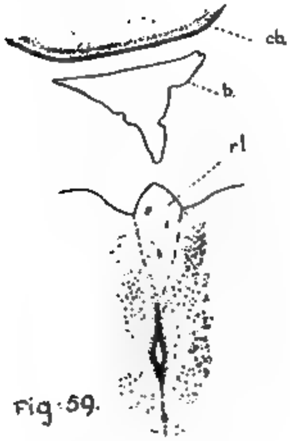
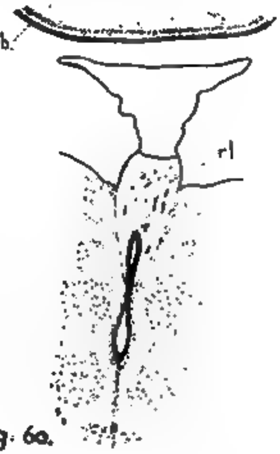


Fig. 59.



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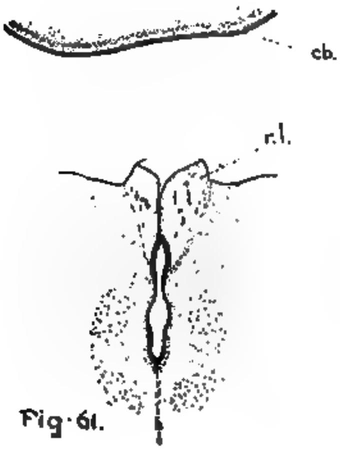

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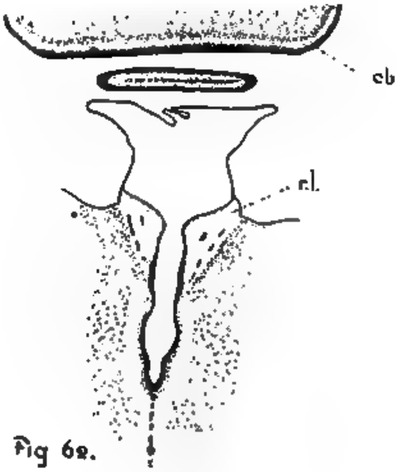

Fig. 62.

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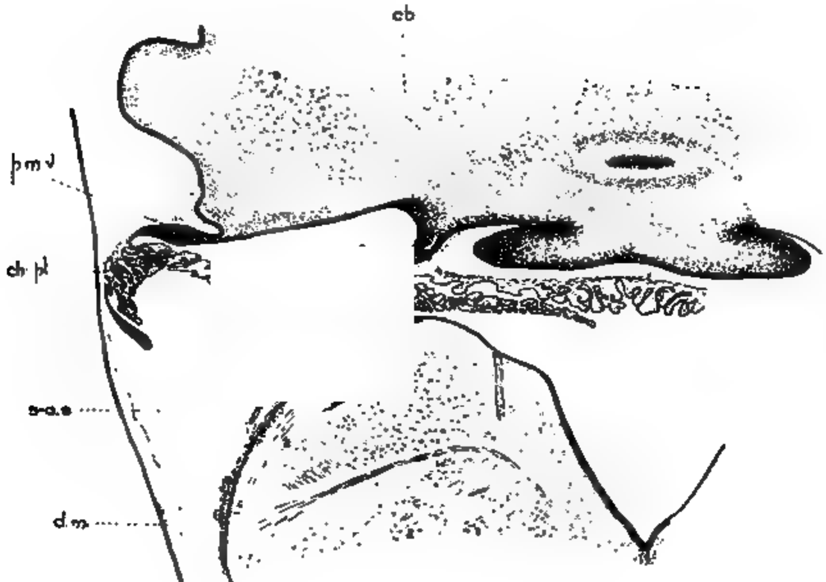


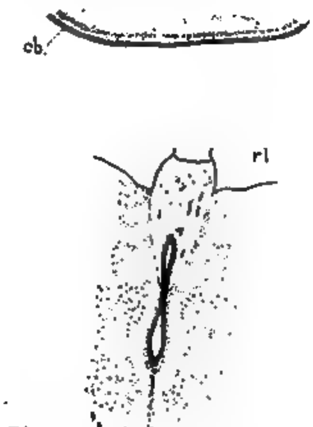
Fig. 63.

p.m.v

a.m.v

tr.

Fig



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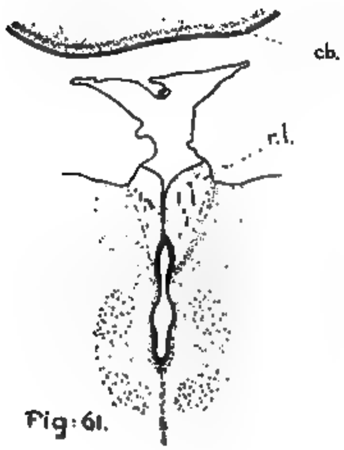

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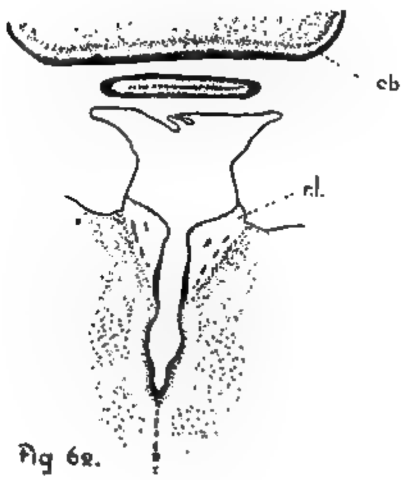

Fig 62.

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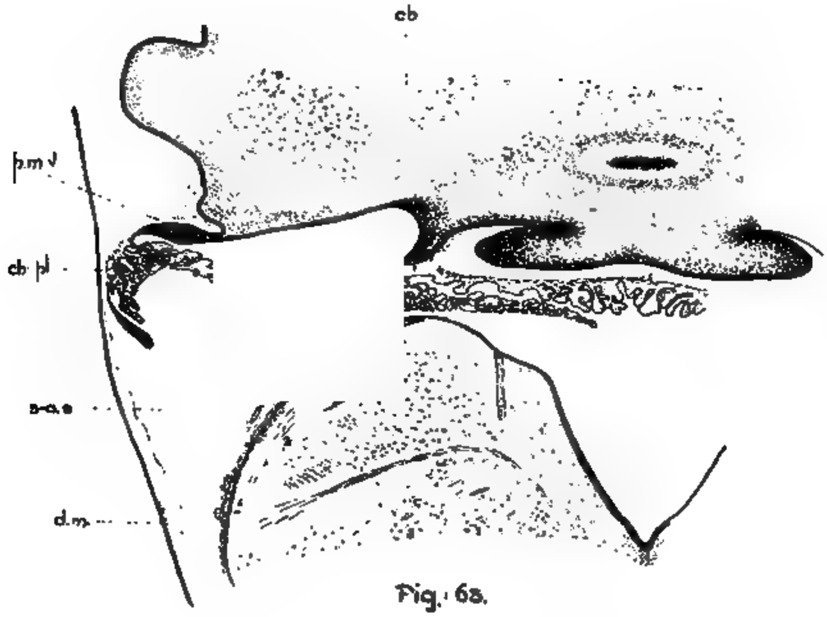

Fig. 6a.

p.m.v

a.m.v

l.r.

PROFESSOR O. CHARNOCK BRADLEY.

A STUDY OF THE ASTRAGALUS.

By R. B. SEYMOUR SEWELL, B.A., *Christ's College, Cambridge, Fellow of the Anthropological Institute.*

PART IV.

THE CAPUT.

THE *caput*, or head of the astragalus, comprises all the smooth articular portion of the bone lying anterior to the neck.

In shape this surface is, as has been pointed out by Barclay Smith (2), of an ellipsoidal character, and in consequence the astragalo-calcaneo-navicular joint must be placed among the condylarthroses: in the Egyptian astragalus the long axis of the head, around which movement takes place,

a *b*

FIG. 29.—Anterior end of astragalus—showing the inclination of the long axis of the caput to the horizontal plane of the trochlear surface. *a*, Human, *b*, Orang utan.

passes from above and to the outer side downwards and inwards at an angle of approximately 45° with the transverse plane of the trochlear surface; but when we come to the consideration of this axis in the astragali of the anthropoid apes we meet with a considerable difference, for in these animals the long axis of the joint is much more nearly parallel with the trochlear plane.

Aeby (1) has pointed out that the value of this angle increases as we pass from the anthropoid apes to man, and I have since been able to confirm this.

I have also found that we meet with differences in respect of this angle in different human races. Thus in the Egyptian the angle has on the average a value of 43·5°, whereas the average value obtained from thirty-five specimens from Borneo was only 41°.

These varying values can be arranged in order of magnitude as follows:—

Orang (young)	8°
Human (fœtus)	10°
Orang (adult)	12°
Gorilla	12°
Human adult (Borneo)	41°
Human adult (Egyptian)	43·5°

It is evident, therefore, that during the process of eversion of the foot the line of articulation of the caput tali has been rotated in the manner shown.

We also meet with very considerable variation in the value of this angle in individual specimens. Thus in the Egyptian series of bones in No. 642 the angle measured 62°, whereas in No. 502 it was only 25°; and in the collection of bones from Borneo we find almost as great variations—No. 2 presenting an angle of 59° while in No. 33 the value was only 26°.

The surface of the caput is subdivided into several articular facets, although the facility with which the various surfaces can be recognised, varies to a very considerable extent in different specimens; thus in some cases the facets are separated from one another by low intervening ridges, whereas in others all trace of separation is lost and the whole caput presents a uniformly smooth surface.

Turning now to the consideration of the individual facets, the first which we will study is the *facies articularis navicularis*.

This facet occupies the most anterior portion of the caput: in outline it is roughly oval, its long axis corresponding fairly closely with the direction of the long axis of the caput.

The articular surface presents a convex curvature in both the long and the short axes of the facet.

Above and to the outer side the facet is usually sharply marked off from the roughened surface of the collum tali, but in those cases in which a well-marked processus trochlearis is present on the upper surface of the neck the articular surface may be continued on to its anterior aspect; or, again, in rare cases we find that the facet is prolonged backwards along the smooth external margin of the collum so as almost to meet the

trochlear surface on the corpus—a condition of which I have only succeeded in obtaining two examples, Nos. 122 and 754.

Internally and above, the edge of the articular surface is, as a rule, somewhat bevelled off, thus providing a smooth surface, over which the ligamentum talo-navicularis profundum glides.

We may occasionally find a specimen in which the articular surface is prolonged backwards on the medial aspect of the collum tali; and in one case, No. 767, it reached back as far as the facies malleolaris medialis, thus completely obliterating the medial portion of the neck of the bone.

Below and to the inner side the facet becomes continuous with the other articular surfaces of the caput, the lines of separation being as a rule merely indicated by low articular ridges, which are not usually very distinct, but in certain specimens are very well marked.

At the inner border of this facet we meet with two distinct conditions; in the majority of cases—*i.e.* in about 60 per cent.—the margin of the articular surface becomes continuous with the margin of the facet for the tendon of the tibialis posticus muscle, forming a uniform curve, whereas in the other 40 per cent. of the specimens examined this margin is interrupted by a well-marked notch which runs downwards and forwards for some short distance between the two facets.

The inferior or ventral portion of the caput is occupied by two articular surfaces—the facies articularis calcanea anterior externally, and the facet for the ligamentum calcaneo-naviculare inferius internally.

Facies Articularis Calcanea Anterior.—This facet is usually somewhat irregularly oval in outline, but it varies through a considerable range both in its shape and size. The surface anteriorly and above is separated from the facies articularis navicularis by, as a general rule, only an indistinct low ridge, but in certain cases we find that these two surfaces are separated off very distinctly from one another, the angle between them being nearly a right angle. This seems to be particularly the case in those specimens in which the facies articulares calcaneæ anterior et media are fused together to form a single articular surface.

Externally and somewhat posteriorly the facet is sharply marked off from the roughened surface of the sinus tarsi by a prominent and frequently somewhat overhanging border.

At its antero-internal margin it is only separated from the facet for the ligamentum calcaneo-naviculare inferius by an indistinct ridge, while posteriorly it is only indistinctly marked off from the facies articularis calcanea media of the collum tali—the two surfaces meeting at a wide angle.

Occasionally, however, the angle at which these two surfaces meet is

much smaller, and in such cases the two facets are very distinctly marked off from one another.

As I have already pointed out, we occasionally come across a specimen in which the rough internal or external, or more rarely both, aspects of the collum tali are prolonged between these two articular surfaces, so as to separate them either partially or entirely by a narrow band of rough bone; this condition I have found to be present in about 2 per cent. of the specimens which I have examined.

As Barclay Smith has shown (2), there is present in the astragalo-calcaneo-navicular joint a small interarticular ligament, which runs from the head of the astragalus to become attached to the ligamentum calcaneo-naviculare inferius, and when it is well developed this notch or groove between the anterior and middle calcaneal facets serves to give attachment to the fibrous band.

One not infrequently comes across a specimen which presents the extreme opposite condition; in such cases all trace of any distinction between these two facets is completely lost, and one then gets a single elongated articular surface, reaching from the facies articularis navicularis in front to the sulcus interarticularis behind.

In rare instances we find that the facies articularis calcanea anterior is absent altogether. Such a condition existed in six cases—Nos. 193, 201, 572, 877, 910, 931. In these bones the rough external aspect of the collum extended forwards and inwards as far as the facet for the ligamentum calcaneo-naviculare inferius, which was usually in these cases somewhat increased in size (*vide* fig. 29).

With regard to the articular surface, it is found that in the coronal plane, *i.e.* from side to side, it usually presents a slight convexity, but occasionally we come across a specimen which possesses a concavo-convex curvature, the outer part of the facet being convex while the inner portion is concave. In the sagittal plane the curvature is found to vary considerably—more commonly the surface is either flat or slightly concave, and in a few cases a well-marked degree of concavity is present; in other specimens, however, the surface presents a slight though well-marked convex curvature.

Faces for the Tendon of the Tibialis Posticus Muscle.—This articular surface was first described by Fawcett (4). Previous to this, it had always been regarded as part of the facet for the ligamentum calcaneo-naviculare inferius, but, as this observer has pointed out, over the inner side of the caput of the astragalus this ligament is "so thin that it could scarcely cause so well-marked a facet," and hence we must look for some other cause. This, according to Fawcett, is to be be found in the tendon of the

tibialis posticus muscle, "which runs downwards and forwards by the side of the head of the astragalus," being separated from it merely by the thin lateral margin of the ligament.

The facet is roughly quadrilateral in shape and presents two curvatures, being slightly concave from above downwards and convex from side to side.

Anteriorly the articular surface is bounded by the facies articularis navicularis, and posteriorly by the facies articularis calcanea media.

Above and to the inner side the facet is sharply marked off from the

Facet for fibro-cartilago navicularis.

Facet for tendon of tibialis posticus muscle.

Sinus tarsi.

Facies art. calcanea media.

Facies art. calc. post.

FIG. 30.—Norma basilaris—showing absence of the facies articularis calcanea anterior. No. 201.

rough surface of the collum tali, and we not infrequently come across a specimen in which this rough surface is prolonged downwards as a wide notch between this facet and the facies articularis navicularis.

Externally and below the articular surface is bounded by the facet for the ligamentum calcaneo-naviculare inferius, being usually separated from it by a faint ridge; though in a large number of specimens no trace of any separation can be seen, the two facets being indistinguishably blended together to form a single articular surface.

As Fawcett has pointed out, the articular cartilage covering these two facets is very soft and in macerated specimens is usually wanting, thus

leaving rough bare bone; the layer of compact bone which forms the surface is also of a rather delicate nature, and in a large number of specimens has been broken away.

We occasionally meet with specimens which present extra accessory facets; these articular surfaces are of two kinds: (*a*) for articulation with the cuboid bone, and (*b*) for articulation with a little ossicle known as the calcaneus secondarius.

Facet for the Cuboid Bone.—The occurrence of this facet has been recorded by T. Wardrop Griffiths (5) and by Bland Sutton (3). The facet

Facies articularis navicularis.

Facets accessoria cuboidea.

Articular surface for fibro-cartilago navicularis.

Facies articularis calcanea anterior

Facet for tendon of m. tibialis posticus.

Facies articularis calcanea media.

FIG. 31.—Norma basilaris—showing accessory facet for the cuboid.

is of very rare occurrence, and I have only succeeded in finding it in two specimens.

In shape the articular surface is roughly quadrilateral (fig. 30), and is only marked off to a very slight extent from the rest of the articular surface of the caput.

The facet is situated in front and slightly to the outer side of the facies articularis calcanea anterior, which is somewhat diminished in size: to the inner side is the facet for the ligamentum calcaneo-naviculare inferius, and between these two articular surfaces is a low rounded ridge, while anteriorly the area is bounded by the facies articularis navicularis.

In one specimen, No. 493, the facies articularis calcanea anterior was reduced very considerably in size and formed merely a narrow articular surface in front of the facies articularis calcanea media (*vide* fig. 31). In front of this narrow facet was a triangular area with slightly raised edges and a smooth concave surface, which was perforated by several small foramina.

The base of the triangle was towards the outer side of the caput, and here the facet blended with the rough external surface of the collum tali.

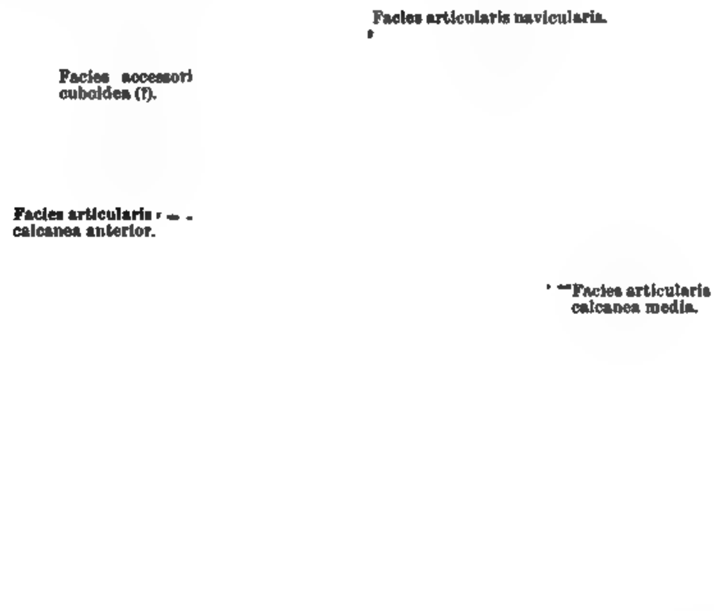

FIG. 32.—Norma basilaris—showing accessory facet probably for the cuboid. No. 493.

This concave area was apparently for articulation with some other part of the tarsal skeleton; and as the position it occupies is identical with that of the facet for the cuboid, I am inclined to think that it must have been for this latter bone, though the articular surface differed in several particulars from the conditions usually present in the facet.

Facet for the Calcaneus Secondarius Ossicle.—As Professor Pfitzner (7) has pointed out, this ossicle is situated at the anterior end of the os calcis and somewhat to the outer side, and was present in 2 per cent. of the feet examined.

In a certain number of cases this ossicle comes in contact with the caput tali and gives rise to an articular facet. Such a facet I found to be present

in fourteen specimens—Nos. 20, 23, 436, 450, 501, 536, 612, 614, 660, 741, 809, 810, 816, 969.

In all the cases the facet was roughly rhomboidal or oval in shape and was situated on the under or ventral surface of the caput (*vide* fig. 32). In front, the articular surface abutted on the facies articularis navicularis; to the inner side was the facet for the ligamentum calcaneo-naviculare inferius, while to the outer side and behind the area was limited by the facies articulares calcaneæ anterior et media respectively.

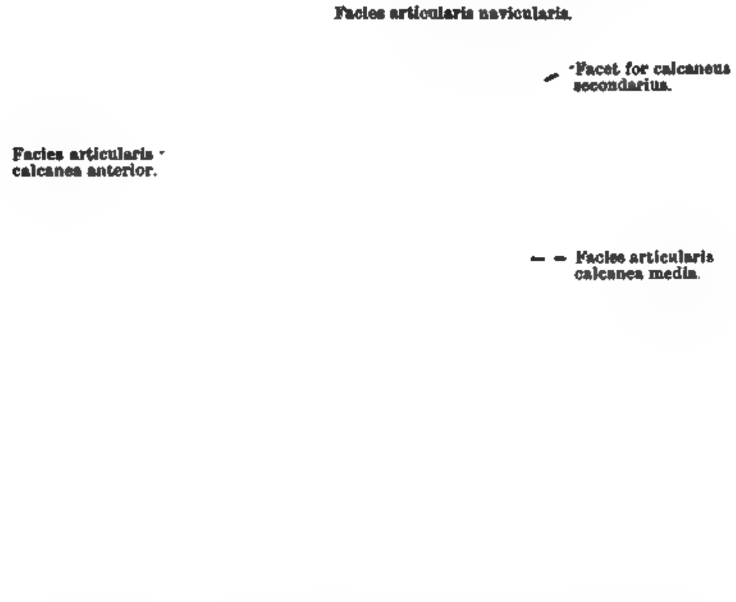

FIG. 33. —Norma basilaris —showing facet for the calcaneus secondarius ossicle. No. 450.

Architecture of the Bone.—One cannot leave the subject of the astragalus without saying a few words with regard to the arrangement of the lamellæ in the cancellous tissue of the bone.

In the astragalus, as in all other bones, the lamellæ are arranged in definite planes corresponding to the lines of force which act upon the various surfaces.

Taking first of all the arrangement in the corpus, we see that in a transverse vertical section two sets of lamellæ can be distinguished—(*a*) a vertical and (*b*) a horizontal set, crossing one another at right angles.

The vertical set run in the sagittal plane from the trochlear surface above downwards to the facies articularis calcanea posterior, and thus serve

to transmit the weight of the body from the tibia above to the os calcis below.

The horizontal set of lamellæ runs from side to side of the bone, thus strengthening the two malleolar facets and at the same time supporting the vertical set.

FIG. 34.—Showing the arrangement of the lamellæ in a trans-section through the corpus.

Turning now to a section of the bone in the sagittal plane we see that the superficial compact bone is specially thickened in two regions—at the portion of the bone on the under surface that forms the roof of the sulcus interarticularis, and at the neck on the upper surface. The horizontal set

FIG. 35.—Showing the arrangement of the lamellæ in a sagittal section through the astragalus.

of lamellæ which we observed in the previous section, we now see to be running from the trochlear surface forwards and downwards through the neck to end mainly in the upper part of the facies articularis navicularis; in the neck region this set is reinforced by a series of strong lamellæ, which arises from the specially thickened layer of compact bone which we have already mentioned.

In the neck and head region we also get another set of lamellæ, which

in a sagittal section are seen cut across: these start from the facies articularis calcanea media on the under-surface of the neck, and curve upwards and forwards and finally end in the lower portion of the facies articularis navicularis.

Just above the sulcus interarticularis the cancellous tissue is of a comparatively open character.

As has been pointed out by Sir George Humphry (6), the consideration of the arrangement of lamellæ in the astragalus leads one to conclude that the weight of the body is transmitted either downwards and backwards on to the os calcis, or forwards to the navicular, and that very little of the weight falls on that part of the head which is supported only by the ligamentum calcaneo-naviculare inferius and the tendon of the tibialis posticus.

In conclusion, I wish to record my sincerest thanks to Professor Macalister, who has given me considerable assistance during this work, and also to Dr W. L. H. Duckworth and Mr Oldfield Thomas, who have kindly permitted me to examine the anthropoid astragali in the various collections under their charge.

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THE ARRANGEMENT OF THE ELASTIC FIBRES IN THE BRONCHI AND LUNG.

By JAMES MILLER, D.Sc., M.D., M.R.C.P.Ed., *Special Lecturer on Bacteriology in the University of Birmingham.*

SINCE elective staining methods for elastic fibres came into general use, a considerable amount of attention has been directed to the arrangement of these fibres in the various organs and tissues of which they form an important part. It would appear, however, that, in the case of the lung, this attention has not been of the degree that is warranted by the prominent part which elastic tissue bears in the structure of that organ. It is not too much to say that elastic fibres form so essential a part of the lung framework, that it is impossible to obtain a correct idea of the architecture of the organ without making use of one or other of the elective staining methods.

It was a realisation of the above facts which tempted the author, at the commencement of a research into the changes which the elastic fibres of the lung undergo in pathological conditions, to direct his attention to the normal arrangement of these fibres. The temptation was all the greater as, in certain diseased conditions, the normal structure of the lung is elucidated in quite a striking manner. This is all in the way of apology that the author offers for trespassing on the domain of the normal histologist.

Among histologists who have directed special attention to the elastic fibres are Gardner (1), Teuffel (2), and Linser (3). The two former concern themselves chiefly with the development of the fibres in the embryo; the last gives the only connected account, so far as the author knows, of the arrangement of the elastic fibres in the normal adult lung.

As regards technique, all that the author claims as new is the employment of the Aschoff-Becker carbonic-acid-freezing microtome for cutting the sections. The above-mentioned observers used paraffin and celloidin for embedding their tissues. The advantages of this freezing microtome are these:—In the first place, there is no shrinkage of tissue from heating or from prolonged treatment with chemicals. In the second place, large sections can be obtained ($1\frac{1}{4} \times 1$ inch), and the advantage of these in studying lung structure cannot be too strongly emphasised. Lastly, the sections may be thick (30–40μ), and yet with Weigert's method detail is perfect. The advantage of thick sections is readily realised when one

remembers the sinuous course of the fibres which one proposes to study. It must be stated, however, that a perfectly normal lung does not cut well when frozen. On the other hand, one which is slightly consolidated cuts excellently, and the author has no hesitation in asserting that such a lung shows up the structure of the organ better and more naturally than the normal lung itself. This is largely due to the fact that when the pleura is opened, the lung, if it be normal, collapses to a third of its original bulk, whereas the alveoli of the consolidated organ remain distended. Further, the changes which the elastic fibres undergo in acute inflammatory conditions are so slight, as a rule, that they may be neglected. Even in gangrene, as is shown in fig. 2, the elastic structure of the lung may be completely preserved in an area which, with ordinary staining methods, would appear structureless.

The author does not propose to discuss in any detail the relative merits of the two chief elastic tissue staining methods—the Unna-Taenzer and the Weigert. Each has its advocates—Krystalowicz (4) and Gardner supporting the former, Herxheimer (5) and Fischer (6) recommending the latter. All that the author feels justified in saying is that he has found Weigert's resorcin-fuchsin (the stain which he has used almost exclusively) easily prepared, rapid, and reliable.

With regard more particularly to the preparation of the stain, the details will be found in most of the modern text-books on methods, or in Weigert's original article (7). The fact that the iron preparation mentioned in this article is from the German Pharmacopœia, may prove somewhat puzzling. The author has, however, found that the amount of the iron does not really matter so long as there is an excess. The stain when fresh made is, in the author's experience, not absolutely elective. It improves, however, on keeping and after repeated use, although the time required for staining the fibres properly is thereby lengthened.

As regards the nature of the stain, very little is known except that it is a combination of iron, resorcin, and fuchsin. Fischer, who has studied this question very fully, has shown that both the resorcin and the fuchsin may be replaced by other substances—the former by orcein or pyrogallol, the latter by visuvin, safranin, or thionin. He has proved, further, that, if the fuchsin be left out of the process, a fluid is obtained which, although it does not stain the elastic fibres, apparently acts as a mordant, so that subsequent treatment with alcoholic fuchsin gives a result indistinguishable from that obtained with the original Weigert stain.

With regard to the question as to whether all that is stained by this method is of the nature of elastic tissue, the author's experience is that, besides the elastic fibres, only the cartilage plates of the bronchi remain

stained after treatment with absolute alcohol, and these only in part. As regards the other question—whether the method is a true test for the existence of elastic fibres—Fischer (8) concludes, after comparing with other

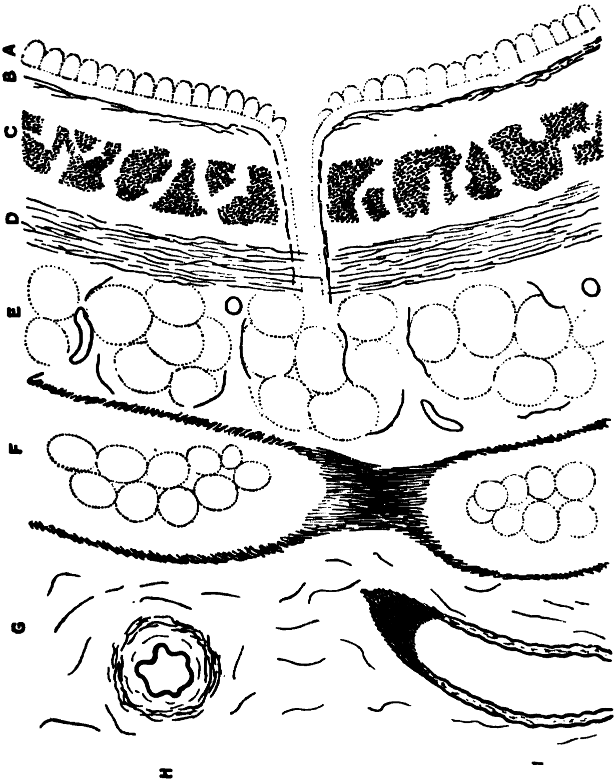

Fig. 1.—Arrangement of elastic fibres in large bronchus. A, epithelium; B, sub-basement membrane layer; C, longitudinal layer; D, muscular layer; E, stratum of mucous glands containing a few irregular fibres and those in connection with vessels; F, layer enclosing cartilage nodules; G, fibrous tissue of wall containing some irregularly-running fibres, also vessels; H, bronchial artery; I, pulmonary artery.

tests such as caustic potash and orcein, that the Weigert stain is at least as reliable as these.

Commencing with the larger bronchi, one finds, as a rule, four distinct layers of elastic fibres (fig. 1).

1. A layer of fine interlacing fibres running longitudinally and circularly, situated immediately under the basement membrane (fig. 1 (B),

and fig. 3). This layer is not always quite distinct or continuous: it is better developed in the adult than in the child. Its fibres are prolonged, as a rule, into the ducts of the mucous glands, and unite with the elastic fibres surrounding these structures. So far as the author is aware, this layer has not yet been described. One might term it the sub-basement membrane layer.

2. Underneath the above and distinct from it there is a broad layer of thick, closely-set fibres gathered into more or less distinct and separate

FIG. 2.—Lung of child, gangrene, × 30. Necrosis of cellular structures of lung. Elastic fibres preserved. Shows arrangement of fibres in walls of vessels, terminal bronchioles, and alveoli.

bunches of irregular shape, between which vessels and the ducts of mucous glands pass (fig. 1 (C), and fig. 3). This layer is arranged longitudinally, or somewhat obliquely, and is certainly the most constant and most distinct layer in the walls of the larger air-tubes. It communicates with the previous layer by means of finer fibres. The term longitudinal would distinguish this layer from the others.

3. The third layer (fig. 1, D), which lies immediately subjacent to the previous one, consists of fine sinuous fibres enveloping and intersecting the muscularis mucosæ. It is, of course, circular in its arrangement, and it splits to enclose the vessels and the ducts of mucous glands which pass through it. This layer might be termed the muscular layer.

4. Lastly, there is a circular layer (fig. 1, F) of thick, closely-set fibres which split to enclose the cartilage nodules and the individual fibres of which appear to merge with the cartilage substance. One might call this the cartilage layer.

Between the two latter layers there lie the mucous glands, which possess a few elastic fibres running irregularly in addition to those in direct connection with vessels. Outside the fourth layer there are numerous irregular fibres, and also those forming the walls of vessels. The above

FIG. 3.—Bronchus of child stained with Weigert's method, × 570. Shows remains of epithelium homogeneous basement membrane, sub-basement membrane layer, and longitudinal layer of elastic fibres.

arrangement holds good for trachea as well as for the larger bronchi; but in the trachea the first three layers are insignificant when compared with the cartilage layer, and the muscular layer is patchy in its distribution.

As one passes from the larger bronchi to the smaller one finds that these layers, with the exception of the second—the longitudinal layer—gradually disappear. The sub-basement membrane layer is the first to go: the cartilage layer disappears with that structure. Similarly, the muscular layer ceases when the muscular fibres no longer form a distinct coat. The longitudinal layer, however, persists, and merges with the fibres forming the walls of the terminal air-passages.

Turning to these one finds that, in the terminal bronchioles (fig. 2), the elastic tissue has been reduced to a single stratum of closely-set, fairly stout fibres situated immediately under the basement membrane. In the alveolar passages a similar arrangement prevails, but the layer is here interrupted by openings into air-vesicles. At these openings there is an apparent thickening, produced by a gathering together of the elastic fibres to form a stout ring or collar (fig. 2). From the alveolar passages onwards into the infundibula and alveoli the elastic fibres do not form a dis-

FIG. 4.—Lung of child, × 570. Elastic fibres in walls of alveoli and in interalveolar septa well seen.

tinct and continuous coat, but occur in the form of bands of sinuous fibres which lie under the endothelium. These bands of fibres unite with similar bands in the walls of neighbouring air-passages. In the infundibula the thickenings at the openings of air-sacs are, of course, very numerous.

In connection with the alveoli themselves, these bands, consisting of fibres of varying thickness, pass in an irregularly sinuous manner spreading out and uniting with similar bands, and becoming gradually thinner by giving off fibres which become finer and end in the walls of the air-sacs (fig. 4). Where exactly these terminate, and whether they are continued for a time as fibres not of an elastic nature, it is impossible to say.

The fibres of neighbouring alveoli communicate freely with one another, uniting and separating again in the interalveolar septa (fig. 4). As previously mentioned, there is a gathering together of the fibres to form a collar at the openings of the air-sacs into infundibula and alveolar passages.

Turning to the pleura, one finds a layer of interlacing fibres immediately under the endothelium. The fibres vary a good deal in thickness, and may be round or flattened. They pass in all directions, crossing one another, uniting, and separating again, thus forming a dense network. This layer

FIG. 5.—Oblique section of branch of pulmonary artery, × 570. Elastic tissue of vessel seen to consist of two layers of longitudinal fibres, between which is a layer of circular fibres.

is frequently duplicated, the second layer lying immediately under the first. Whether this duplication is found more frequently in certain positions, and whether there is any individual variation, the author has not yet decided. Under these layers there is a band of fibrous tissue which contains occasional elastic fibres, also those connected with the walls of vessels. The elastic fibres of the nearest alveoli abut on this layer of fibrous tissue; but they cannot be said to form a distinct and continuous stratum, such as Linser describes.

With regard to the interlobular septa, in the author's experience, under normal conditions, elastic fibres do not exist apart from those in connection with vessels.

Turning, in the last place, to the vessels themselves, one finds that a

distinction must at once be made between bronchial vessels and pulmonary vessels proper as regards their elastic coats. The former show the ordinary arrangement—viz., in the case of the arteries an internal elastic lamina (or, more properly speaking, a layer of thick interlacing fibres), a few fine fibres in the middle coat, the number increasing with the size of the vessel, and outside this a varying number of more or less complete layers in the adventitia. In the case of the veins the arrangement of the fibres is similar, but the layers are not so thick nor the fibres so numerous.

In the case of the pulmonary vessels the difference between artery and vein is not so marked, and, in arterioles and venules, it is no longer possible to make the distinction. The capillaries of the alveolar walls have no distinct coating of elastic fibres; this appears first in the small vessels lying in the fibrous tissue between the groups of air-sacs (fig. 2). The elastic coat of such a vessel consists of a single layer of longitudinally-running fine elastic fibres, lying immediately under the endothelium. As the vessel increases in size a second layer of fibres, also longitudinal, appears, and between the two is a circular layer the fibres of which lie between the muscular fibres of the media (fig. 5). This type of vessel, with two longitudinal layers and a circular one between, is the commonest one found in the lung. As the vessel increases in size, more longitudinal layers are added alternating with circular. When a branch leaves or joins a vessel it is, of course, the internal longitudinal layer which is continued as the innermost layer of the smaller vessel, the remaining layers being continued or rapidly fading out according to the size of the branch.

In the above description there is little that is absolutely new. Linser describes the arrangement of the fibres very much as the author has done; he makes no mention, however, of the sub-basement membrane layer. That this is a layer distinct from the longitudinal is brought out in certain pathological conditions. For example, in a case of acute bronchitis resulting from ammonia gas-poisoning, the author found that a stratum of necrosed tissue in the lumen of the bronchi proved to be this layer of fibres along with the basement membrane, which had become completely separated from the subjacent tissues. Then, again, Linser fails to mention the frequent duplication of the sub-endothelial layer of fibres in the pleura. This is a subject worth investigating with regard to the question as to what parts of the visceral pleura show this double layer.

With regard to the structure of the vessels, Linser states that the internal elastic lamina consists of fine parallel-running fibres with occasional cross fibres. As the author has pointed out, and as is shown in fig. 5, these cross fibres belong to a distinct layer and do not intersect the longitudinal fibres of the other coats.

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A NEW METHOD OF DEMONSTRATING THE TOPOGRAPHICAL ANATOMY OF THE ADULT HUMAN SKULL.

By SYDNEY R. SCOTT, M.S., M.B. Lond., F.R.C.S. Eng., L.R.C.P. Lond.

IN this paper I do not propose to discuss the subject of cranial topography from an anthropological point of view: I propose rather to describe a system by which it is possible to demonstrate the cranium by means of diagrams and drawings. To those naturally skilled in draughtsmanship, perhaps such a system as that which I bring forward appears unnecessary. But I know of no method which has been prepared for the purpose of introducing to the uninitiated the manner in which the average skull can be correctly reproduced by diagrams and drawings, from below, from above, from the front, and from the side. To do this an accurate knowledge of the topography of the different cranial foramina and processes is necessary, and, by a series of some four hundred measurements, I have striven to find the least variable landmarks of the skull, upon which to base this system.

One finds that whereas the variations in contour and dimensions of the vault of the adult skull are considerable, the variations in the distances between certain foramina and other readily identified landmarks of the base and facial portions of the skull, are comparatively small.

The degree of prominence of the malar bones, and the curvature of the zygomatic arch, are subject to variation. The variations in shape and size of the alveolar arch depend upon the presence or absence of sound teeth; thus it is in the vault, zygoma, and alveolar arch that the widest degrees of variability are found.

Certain well-known data have been confirmed, and additional data have been obtained from the records of the series of four hundred measurements which have been specially taken in twenty different skulls.

These observations reveal the remarkable approximate constancy in relation of the chief foramina and processes of the anterior half of the base of the skull, and of the lateral aspect of the cranium and also of the lower half of the facial aspect.

The relations of these foramina to each other can be represented by geometrical figures, which are accordingly constructed and serve as a groundwork, upon which the chief foramina can be indicated; and the variable elements, *e.g.* the contour of the vault, are added last of all.

1. THE NORMA BASILARIS.

To illustrate the norma basilaris, two triangular figures are constructed as follows (see fig. 1):—[1]

C N S and C N S″ are two right-angled isosceles triangles, the side C N being common to both triangles and equal to C S and C S″.

Then the points N, S, and S″ correspond to the relative positions of the post-nasal spine and the two stylo-mastoid foramina respectively, while C corresponds to a point which would be just behind the basion. C is the central point of the base of the skull, and on an average is within the foramen magnum and half a centimetre from the anterior margin of that foramen. For practical purposes we may remember that the basion is just in front of the central point.

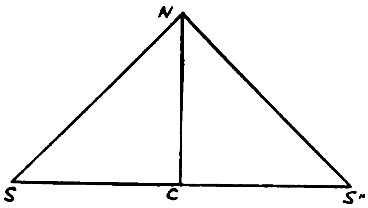


FIG. 1.—N, the post-nasal spine ; S, S″, the stylo-mastoid foramina ; C, the "central point" (in the average adult skull half a centimetre behind the basion).

The line C N is then prolonged to A, making N A equal to C N: A is joined to S and S″ respectively, thus another isosceles triangle, S A S″, is produced (fig. 2).

The point A corresponds to the position of the anterior margin of the anterior palatine fossa.

The sides A S and A S″ represent the well-known guide-lines to the following foramina etc.:—The anterior palatine fossa, the posterior palatine foramen, the pterygoid fossa, the foramen ovale, the foramen spinosum, the vaginal process of the tympanic plate, the stylo-mastoid foramen.

The posterior palatine foramen is situated on the line A S (we may call this the palato-styloid line), two-fifths the distance from the point A. (For the uniformity of this position, see charts 10 and 11.)

Midway between the posterior palatine foramen and the stylo-mastoid

[1] The illustrations accompanying this paper have been produced by following the description given in the text, and without reference to any skull or any other illustration. As mentioned in the text, it has been my purpose to devise a method whereby anyone unskilled in perspective drawing can delineate the essential topographical features of the skull merely by applying accurate anatomical knowledge.

foramen of the same side, is the narrow partition of the sphenoid, which separates the foramen ovale and the foramen spinosum—the latter being on the palato-styloid line, the former being generally a little to the inner side of that line, though it also is sometimes on the palato-styloid line. It will be noticed that the anterior two-fifths of the palato-styloid line corresponds to the hard palate, the posterior two-fifths to the part of the base between the stylo-mastoid foramen and the foramen spinosum, while the middle fifth of the line runs across the pterygoid fossa.

As regards the hard palate, its length is a quarter that of the whole length of the base and its posterior lateral angle is just behind the posterior palatine foramen, while the outline of the hard palate resembles that of a Norman arch.

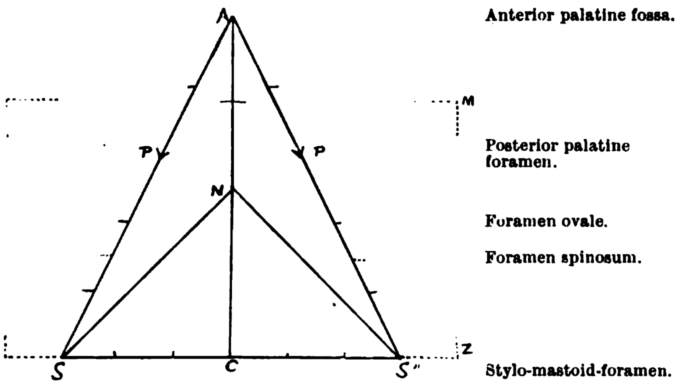


FIG. 2.

With respect to the foramen magnum, we have seen that its anterior margin lies half a centimetre in front of the "central point." The foramem is nearly circular, and its diameter is equal to a sixth of the total length of the base of the skull (see charts 6 and 7).

The external occipital protuberance varies in position more than do the other landmarks above mentioned; the protuberance is as a rule, however, about half-way between the posterior margin of the foramen magnum and the posterior outline of the vault of the skull. The exact position varies with the shape of the vault.

The median transverse line on each side either bisects the middle, or the anterior and middle thirds, of the occipital condyle, and skirts the posterior margin of the jugular foramen; it next crosses the stylo-mastoid foramen, and, if prolonged, runs along the tympanico-mastoid fissure to the posterior margin of the external auditory meatus (figs. 3 and 4).

If the stylo-mastoid foramen of one side is joined to the opposite

posterior palatine foramen, the line corresponds to the direction of the carotid canal. The two "carotid lines" intersect each other on the posterior margin of the vomerine plate (fig. 3). The entrance to the canal lies immediately in front of the middle of the jugular fossa, and the foramen lacerum medium lies on the "carotid line," nearer the middle line than, and internal to, the foramen ovale (fig. 3).

The root of the internal pterygoid plate runs into the anterior margin of

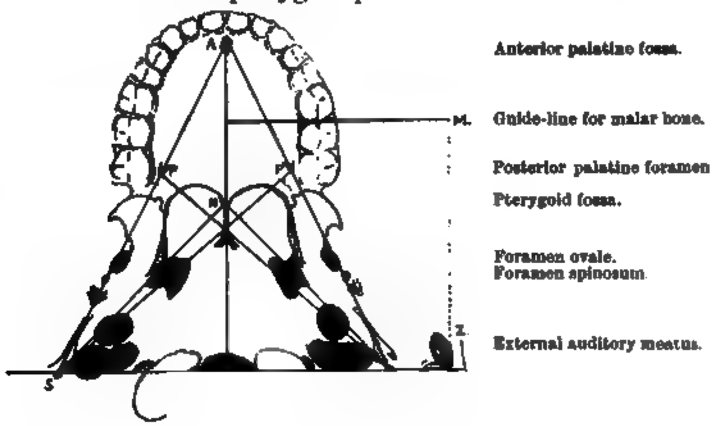


FIG. 3.—A S′ = "palato-styloid line," prolonged backwards, P S″ = "carotid line"; S S″ = mid-transverse line; M Z = malar-zygomatic guide-line, merely giving an approximate guide for zygoma.

the foramen lacerum medium, and the root of the external pterygoid plate runs into the anterior margin of the foramen ovale (figs. 3 and 4).

If the "carotid line" be prolonged backwards it crosses the apex of the mastoid process, and if the palato-styloid line be prolonged backwards it runs along the digastric fossa (figs. 3 and 4).

The superior and inferior curved lines of the occipital bone curve outwards and forwards from the external occipital protuberance, and from the external occipital crest towards the mastoid process and the styloid process respectively (fig. 4).

Turning to the zygomatic arch, the anterior limb and the three posterior roots are constant; but the curvature of the arch and the extent of protrusion of the malar bone forwards and outwards varies, as is well known, in different skulls (figs. 3 and 4).

The zygomatic processes of the temporal bones run forwards, approximately parallel with each other (fig. 3, Z M, and fig. 4). The malar process of the superior maxilla juts directly outwards from the middle of the

Zygomatic arch.

Eminentia articularis.
Pre-glenoid tubercle.

Post-glenoid tubercle.

Supra-meatal crest.
Styloid process.

Mastoid process.
Digastric fossa

Inferior } "curved
Superior } lines."

Fig. 4.

outer surface of the latter bone (fig. 3, M, and fig. 4). The eminentia articularis is level with the foramen ovale (figs. 3 and 4). The post-glenoid tubercle is level with the entrance to the carotid canal and in front of the external auditory meatus. The supra-meatal crest can be seen passing back above the external auditory meatus (fig. 4).

2. The Skull in Horizontal Section. Cranial Fossæ.

We may now consider the internal aspect of the base of the skull; the vault having been removed, fig. 5 shows how we may apply a knowledge

of the topography of the norma basilaris to demonstrate the cranial fossæ, by first representing the positions of those foramina which are visible from above as well as from below (see left-hand side, fig. 5). The original scaffolding of triangles has been removed, so that attention should be first directed to the following foramina and other landmarks which are represented on the right-hand side as viewed from below, and on the left-hand side as viewed from above:—Foramen ovale, foramen spinosum, foramen lacerum medium, foramen magnum.

FIG. 5.

The internal occipital protuberance corresponds approximately to the external protuberance, but is at a little higher level. The lower margin of the sulcus of the lateral sinus corresponds approximately to the superior occipital curved line.

The outline of the skull in horizontal section is approximately ovoid, and the transverse diameter is two-thirds the antero-posterior diameter (see charts 1, 14, 15, and 16).

Fig. 5 shows the transverse lines constructed to divide the antero-posterior diameter into four equal parts. Of these the anterior coronal line,

as we may call it, gives the anterior boundary of the temporo-sphenoidal fossa, and the posterior coronal line gives the extreme posterior limit of the temporo-sphenoidal fossa where the superior margin of the petrous portion of the temporal bone joins the vault.

The mid-coronal line lies half a centimetre behind the basion, and crosses the anterior condyloid canal, the jugular foramen, the internal auditory meatus, and then passes across the posterior margin of the entrance to the external auditory meatus. Thus the mid-coronal line crosses the points of

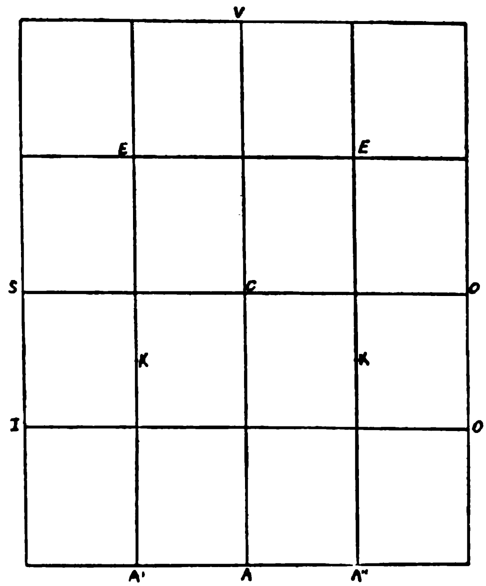


FIG. 6.

exit of the 7th, 8th, 9th, 10th, 11th, and 12th cranial nerves from the cranial cavity (see figs. 4 and 5).

3. NORMA FRONTALIS.

To represent the skull from the front, we draw a rectangular parallelogram, of which the adjacent sides are as 6 to 7 (fig. 6; charts 14, 15, 16, 17).

Through the centre of this parallelogram a horizontal line is drawn. This is the mid-horizontal or supra-orbital line S O (fig. 6; chart 18). Half-way between this and the base we draw another horizontal line; this is the inferior quarter or infra-orbital line I O (fig. 6; chart 19).

Next, we divide the base-line into four equal parts; and then erect median vertical and parallel vertical lines from these points of division, A

and A″ respectively (sagittal lines). The middle two-fourths of the base represents the alveolar arch as seen from in front, and each parallel or lateral sagittal line intersects the centre of the corresponding orbit (fig. 6, K).

The margin of the orbit can then be delineated. Sometimes the inner and inferior quadrant of the orbital margin approximately corresponds to the axis of the diagonal of the parallelogram (fig. 6). The transverse diameter of the orbit is equal to the vertical diameter (figs. 6 and 7; charts 18, 19, 20).

The fronto-malar and the fronto-nasal sutures are level with the hori-

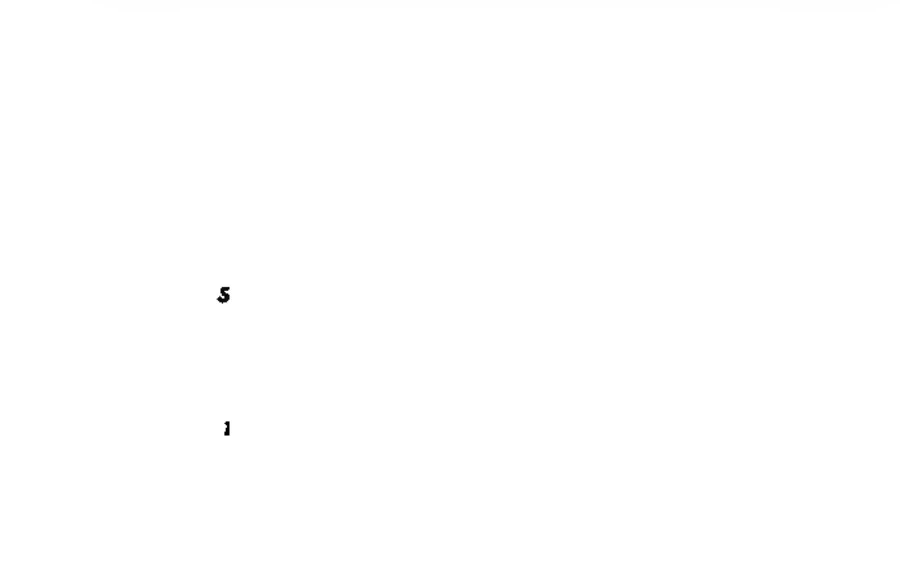


FIG. 7.[1]

zontal plane dividing the upper from the middle third of the orbit (fig. 7). The inferior border of the nasal bone is level with the horizontal plane dividing the middle and lower thirds of the orbit (fig. 7).

The positions of the optic foramen, the sphenoidal fissure, the spheno-maxillary fissure, can then be indicated (see fig. 7). The maximum diameter of the anterior nares is equal to the minimum diameter between the inner margins of the orbits. The nasal septum, middle and inferior turbinates, are visible through the anterior nares.

The infra-orbital line corresponds to the level of the upper border of the zygoma (figs. 7 and 9).

[1] The diagrams illustrating the stages by which fig. 7 is derived from fig. 6 are not given: the description in the text should, however, make these stages clear.

The sides of the upper half of the parallelogram (fig. 6) form tangents of the outline of the vault, which can therefore be drawn in (fig. 7). The shape of the vault varies considerably, as before mentioned, and no attempt is made to depict other than what we may perhaps be allowed to regard as a fairly typical vault.

4. Norma Lateralis.

In several respects this is the most interesting aspect of the skull.

We can deduce the norma lateralis by combining the methods adopted

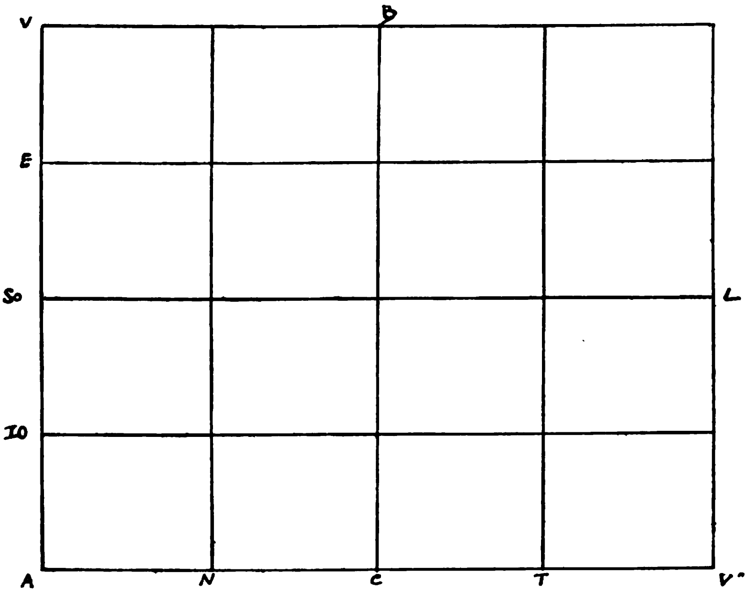


Fig. 8.

in representing the norma basilaris and the norma frontalis. The principle being the same, we take a rectangular parallelogram, the vertical diameter being three-fourths of the antero-posterior diameter (charts 1 and 17). Fig. 8 shows these lines, AV and AV″. Each line is now divided into four equal parts—E, S O, I O, N, C, and T.

Through S O and I O horizontals are drawn, and they correspond to anterior and middle coronal lines of the norma basilaris (fig. 5).

The infra-orbital line corresponds to the upper margin of the zygomatic process of the temporal bone. On the mid-coronal line are the posterior margin of the external auditory meatus and the anterior surface of the mastoid process (fig. 9).

The lower margin of the alveolar arch (fig. 9—A N), as viewed from the side, is placed on the anterior quarter of the base-line AV″; the pterygo-maxillary fissure lies on the anterior coronal line.

The anterior limb of the zygomatic arch juts out from the middle of the superior maxilla, about half-way between the infra-orbital line and the alveolar margin (*cf.* figs. 3 and 4).

Tracing along the inferior border of the zygoma from the external auditory meatus, we can indicate the post-glenoid and the pre-glenoid

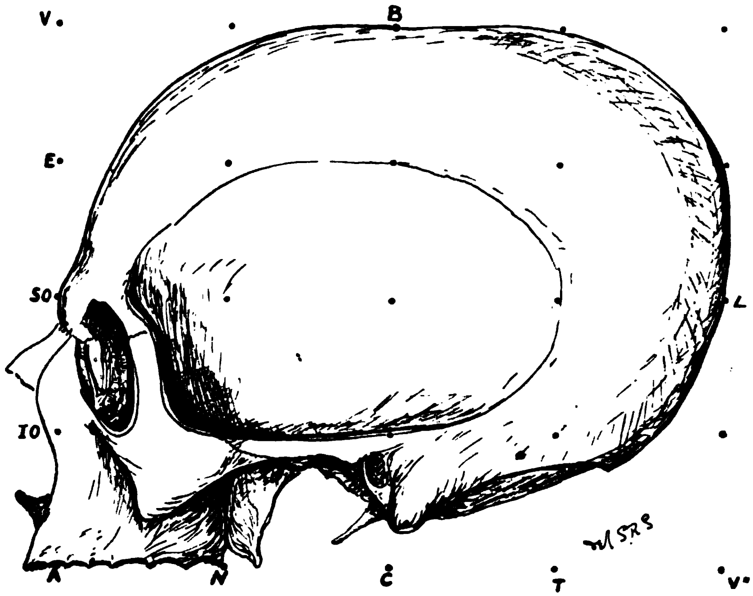


FIG. 9.

tubercles, the latter being midway between the mid-coronal and the anterior coronal lines and corresponds to the eminentia articularis (fig. 9).

The margin of the orbit, as seen from the side, is next represented, and also the fronto-malar and the fronto-nasal sutures, which are level with the junction of the upper and middle thirds of the orbit; the inferior border of the nasal bones lies level with the junction of the middle and the lower thirds of the orbit (figs. 7 and 9). We may rely upon the pre-glenoid tubercle of the eminentia articularis as a safe guide to the structures in the middle fossa of the skull, especially to those in relation to the Gasserian ganglion.

The infra-orbital-zygomatic line prolonged backwards serves as a guide to the highest part of the lateral sinus. Sometimes the postero-inferior

angle of the parietal bone comes well below this line, sometimes it only touches that line. In the latter case the parietal bone forms only a very small part of the sulcus of the lateral sinus.

As regards the base of the skull, the cranial fossæ, and the lateral aspects of the skull, it will be at once evident that the same method of subdivision has been made use of throughout; so we can consider the skull as a whole divided coronally into four sections, by the anterior, middle, and posterior coronal planes, and divided horizontally by the superior, middle, and inferior horizontal planes, the three latter being represented respectively by the frontal, supra-orbital, and infra-orbital planes. (The system might have been further elaborated by use of three sagittal planes—namely, right and left, orbital, and median sagittal planes—corresponding to the vertical lines of the norma frontalis.) The uniformity of this system, applied to the skull as a whole, has the advantage of bringing the third dimension into prominence.

APPENDIX.[1]

The skulls described include European, African, Asiatic, American, and Australasian races.

Considerable differences in contour exist in the adult skull. The differences are chiefly in the vault of the skull, in the alveolar arch, and in the zygomatic arch. It is otherwise respecting the base of the skull and facial regions, where the actual variations are much less.

The most constant topographical relations are found below the supra-orbital line on the facial aspect, in front of the mid-coronal line on the lateral aspect, and in front of the mid-transverse line on the basal aspect.

Skulls examined.

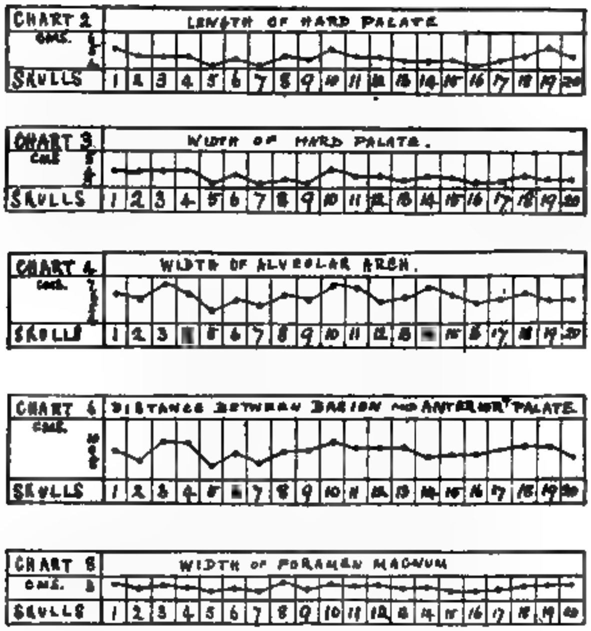
Race.	Catalogue No. St Bartholomew's Hospital Museum.
1. New Hollander	206
2. European	207
3. „	Anatomy Department, Medical School.
4. „	„ „ „
5. „	„ „ „
6. „	„ „ „
7. „	Private collection.
8. „	„
9. New Zealander	203 Catalogue S. B. H. Mus.
10. New South Wales	202
11. „ „	201

[1] I am indebted to the authorities of St Bartholomew's Hospital Museum for permission to refer to the skulls in question for this paper.

Skulls examined—continued.

Race.	Catalogue No. St Bartholomew's Hospital Museum.
12. African	196
13. ,,	194
14. Norman	209
15. Chinese	171
16. Hindoo	179
17. European	159
18. German	167
19. Ancient Briton	166
20. Native Maltese	165

Chart 1. This diameter is taken from the anterior part of the anterior palatine



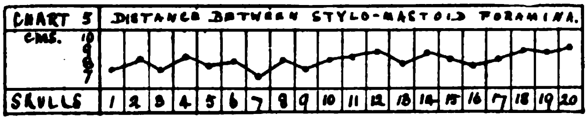
fossa to the vertical tangent of the posterior outline of the vault. In nearly 75 per cent. this measures between 18 cms. and 19 cms. We have taken 18 cms. as

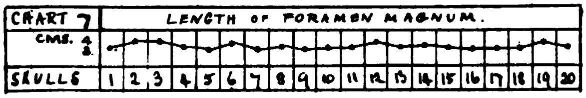
representing a typical case. By comparison with charts 14 and 15 we see the relation of total length, height, and breadth of the skull is as $1 : \frac{3}{4} : \frac{2}{3}$.

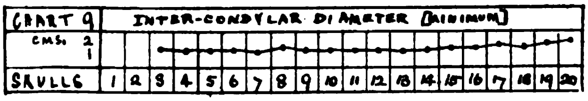
Chart 2. This measurement is taken from the anterior part of the anterior palatine fossa to the post-nasal spine. In over 75 per cent. this is between 4 and 5 cms. We may regard the typical measurement as 4·5 cms.

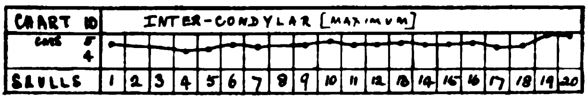
Chart 3. This is the maximum width of the hard palate, and measures between 3·5 cms. and 4·5 cms. 4 cms. will represent the typical case.

Chart 4. The maximum external diameter of the alveolar arch varies with the presence or absence of well-formed teeth. In nearly 75 per cent. this diameter is between 5·5 cms. and 6·5 cms. The average is taken as 6 cms.









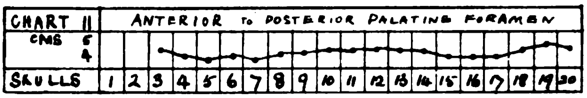


Chart 6. The average distance between the anterior palatine fossa and the basion is 9·2 cms. The average of the majority (in contra-distinction to the average of the total) works out at rather less than 9 cms. For convenience, with a negligible error we take 8·5 cms.

Chart 5. This measurement is between the inner margins of the stylo-mastoid foramina. In over 75 per cent. the distance measures between 8 cms. and 9·5 cms. For the purpose of constructing simple workable geometrical figures, we have taken 9 cms. as representing the typical case. The error is less than two and a half millimetres on each side.

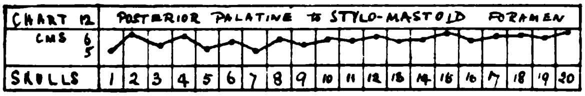
Chart 9. This measurement is taken between the anterior and inner margins of the occipital condyles. Average, 1·5 cms.

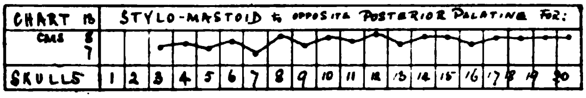
Chart 10. This measurement is taken between the outer margin of the occipital condyles, and is very constant, namely, 5 cms.

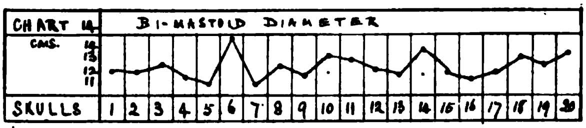
Chart 11. This measurement is taken from the anterior part of the anterior palatine fossa to the posterior margin of the posterior palatine foramen. Average, 4 cms.

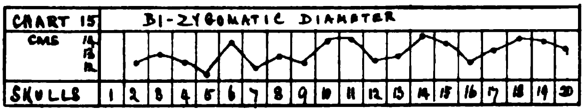
Chart 12. The average is taken as 6 cms.

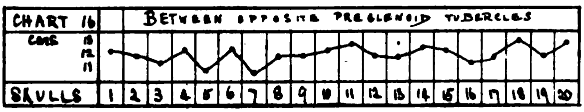
Chart 13. The average is 8 cms. approximately.

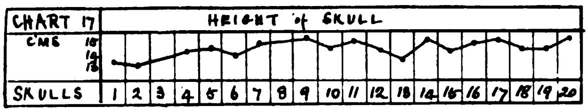


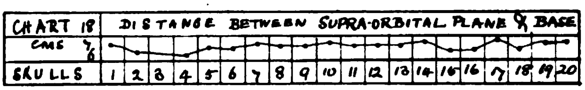












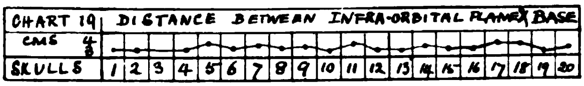


Chart 17. Compared with the average measurement given in chart 1, the average height of the skull to total length is about $\frac{3}{4}$. Variations are, however, considerable as are all variations of the vault in the adult skull.

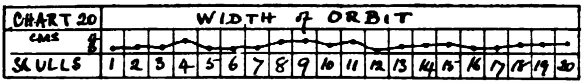
Chart 18. The measurement is taken from a point half-way between the level of the hard palate and the alveolar margin, to the supra-orbital plane.

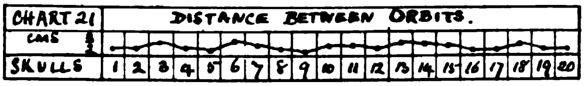
Chart 19. The measurement is taken from the same level as that in chart 18.

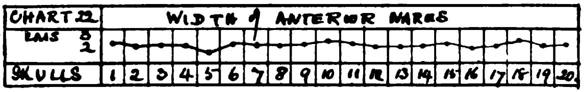
Chart 20. Average, 3·5 cms., the width of orbit being equal to its height.

Chart 21. Average, 2·5 cms. between the inner margins of the orbits.

Chart 22. Average, 2·5 cms.







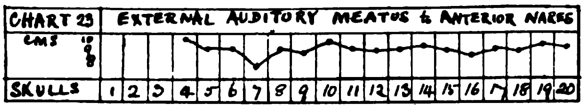


Chart 23. Average, 9·5 cms. This is taken on the lateral aspect, from the posterior margin of the external auditory meatus to the anterior margin of the nasal process of the superior maxilla, in a line parallel with the infra-orbital plane. It is remarkably constant, and is approximately equal to the anterior half of the antero-posterior diameter of the base of the skull. (Compare chart 6.)

A NOTE UPON THE MODE OF TERMINATION OF THE POSTERIOR TIBIAL ARTERY AND NERVE. By CHARLES R. WHITTAKER, L.R.C.S., L.R.C.P., etc., *Demonstrator of Anatomy, Surgeon's Hall, Edinburgh.*

THE posterior tibial artery and the posterior tibial nerve are said to terminate by dividing into their plantar branches at a point three-quarters of an inch below, and behind the internal malleolus. Whilst this statement is sufficiently accurate as regards the artery, a careful examination indicates that the division of the nerve occurs at a higher level. This fact has recently been corroborated by Dujarier.[1]

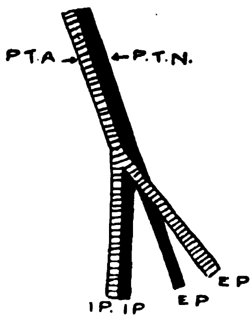


FIG. 1.

A special dissection of the inner ankle was made in eighteen subjects, fifteen of whom were adults, the remaining three being full-time fœtuses. The following table shows how variable is the place of division of the nerve.

No. of subjects.	Distance of bifurcation of nerve above that of artery.
1 Adult	$1\frac{1}{2}$ inches.
2 Adults	1 inch.
8 "	$\frac{1}{2}$ "
4 "	$\frac{1}{4}$ "
3 Fœtuses	Nerve and artery divided at same level.

[1] *Anatomie des membres.* Paris, 1905.

In all the specimens dissected the points of bifurcation were identical on both sides of the body.

From these data it will be noticed—(1) In the adult, the nerve most commonly terminates half an inch on the proximal side of the artery; (2) at birth, the artery and nerve divide an equal distance from the internal malleolus, both plantar nerves passing behind the commencement of the external plantar artery (fig. 1).

In adult subjects the course of the internal plantar nerve is remarkably constant. Lying in the first place external to the posterior tibial artery, intervening between that vessel and the external plantar nerve, it then

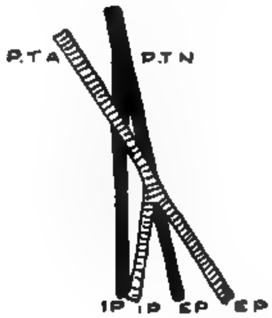


FIG. 2.

FIG. 3.

crosses behind the posterior tibial artery to come into contact with the inner side of the internal plantar artery (figs. 2 and 3). This relation is preserved for a short distance, but ultimately under cover of the abductor hallucis it gains the interval between the two plantar arteries by passing behind the internal.

The course of the external plantar nerve varies somewhat in different bodies. At its origin it is on the outer side of the internal plantar nerve; it next becomes an external relation of the posterior tibial artery; and lastly, in fourteen cases, dipped under the bifurcation of that artery to lie along the inner side of the external plantar artery (fig. 2).

In the remaining four cases it gained this position by passing behind the external plantar artery, as in the fœtus (fig. 3).

JOURNAL OF ANATOMY AND PHYSIOLOGY

ON THE SURGICAL ANATOMY OF THE PROSTATE. (The introduction to a discussion on the Surgical Anatomy of the Prostate at the Anatomical Society of Great Britain and Ireland, November 21, 1905.) By J. W. Thomson Walker, M.B., F.R.C.S., *Assistant Surgeon to the North-West London Hospital and to St Peter's Hospital for Stone and other Urinary Diseases.*

I must in the first place thank the Anatomical Society for the invitation to introduce this discussion on the Surgical Anatomy of the Prostate, and I am the more sensible of the honour since I cannot lay claim to rank as a teacher of anatomy.

During the past few years the prostate gland has been the subject of some surgical adventure and much surgical writing. It is but meet, therefore, that the anatomy of the organ should be carefully revised, so that the work and statements of the surgeon and the anatomist may fall into line.

During the renaissance of prostatic surgery, I was struck by the divergence of views that existed, not only in regard to the operative measures, but also in regard to the anatomy of the organ. I found that the standard works on anatomy differed in certain particulars, or even passed by unnoticed, certain points that appeared to be important from the surgical stand-point.

I therefore commenced an investigation in 1902, with the object of tracing the anatomical lines of the operation of prostatectomy. The remarks I shall make to-day are based upon part of this work, and were published in outline in 1904. I have revised the work by recent dissections, and have found no reason to alter the statements then made.

This is neither the time nor the place for a systematic description of the

anatomy of the prostate. I shall only take up certain points which appear to me important surgically.

THE SHEATH.

The prostate is surrounded by a layer of fascia which envelops it except at its basal attachment to the bladder. At the apex of the gland this sheath blends with the muscular tissue surrounding the urethra. Sir

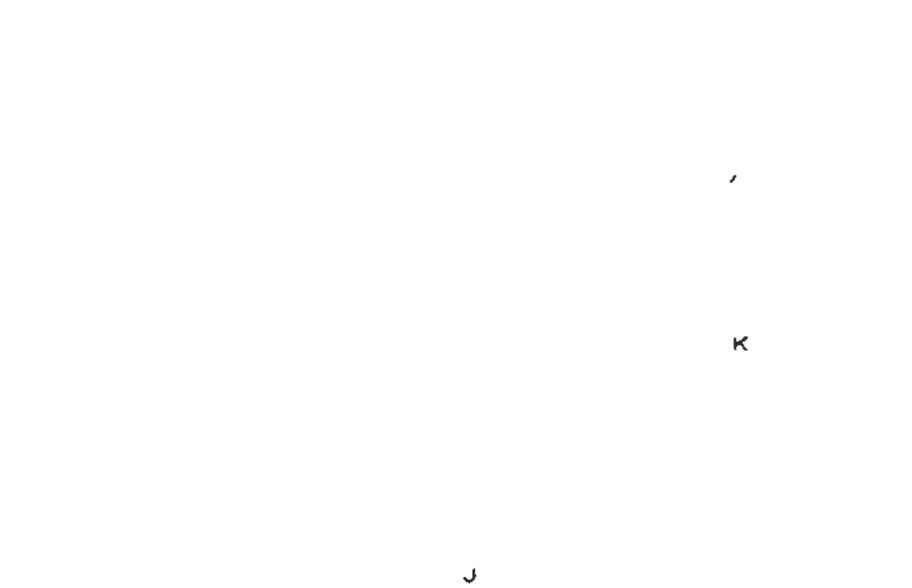


FIG. 1.—Undissected prostate and surrounding tissues removed from body. Anterior surface.

A, Part of anterior surface of prostate between reflected lateral layers of sheath. B, Anterior wall of bladder. C, Rectovesical fascia on upper surface of levator ani muscle. D, Vertical line of reflexion of fascia on anterior surface of prostate. E, Line of reflexion of fascia crossing middle line. F, Upper layer of triangular ligament. G, Apex of prostate showing termination of dorsal vein of penis. H, Striped muscle surrounding urethra. J, Urethra. K, Levator ani muscle.

Henry Thompson described this fascial envelope as the "sheath" in his work on the prostate, and although the term has not been widely adopted by anatomical writers, I have used it here, as it clearly distinguishes this layer of fascia from the tissue immediately surrounding the prostate gland which Thompson called the capsule.

This sheath is derived from the rectovesical layer of pelvic fascia.

The rectovesical layer of pelvic fascia passes inwards from the side wall of the pelvis on the upper surface of the levator ani muscle, and meets the

lateral aspect of the junction of the bladder and prostate, where it becomes firmly attached (fig. 1, C).

A layer of fascia passes up from this attachment and covers the wall of the bladder. A strong layer passes downwards over the lateral aspect of the prostate, and forms the lateral portion of the sheath.

If this lateral layer be traced forwards, it will be found to pass on to the anterior surface of the prostate; but before reaching the middle line it turns

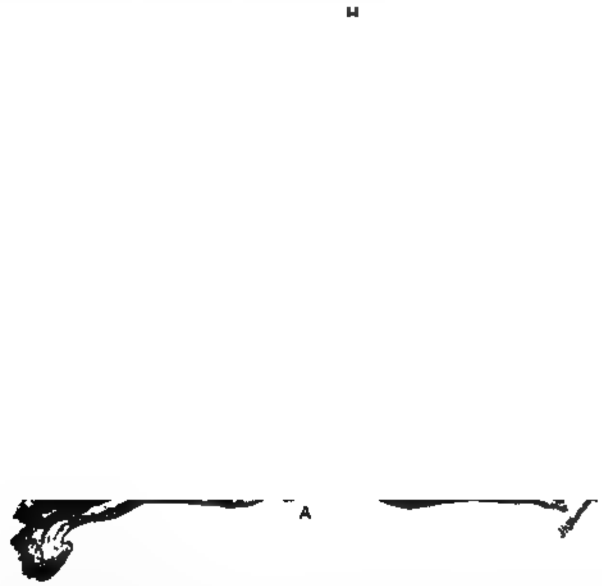


FIG. 2.—Horizontal section of prostate at level of verumontanum.

A, Rectum. B, Areolar tissue between rectum and prostate. C, Rectovesical fascia. D, Layer of fascia on posterior surface of prostate. E, Layer of fascia on side of prostate. F, Reflexion of fascia from prostate. G, Levator ani muscle. H, Layer of fascia on anterior surface of prostate. I, Veins of prostatic plexus. K, Layer of striped muscle. L, M, Margin of stroma forming capsule. N, Anterior commissure. O, Urethra with verumontanum. P, Ejaculatory ducts.

forwards away from the gland, so that at the anterior surface towards the base an interval about the breadth of a finger is left uncovered (fig. 1, A).

As the prostate narrows towards its apex, the line of reflexion, which is vertical, approaches the lateral margin, and, at about the lower third of the organ, appears to pass away from it altogether. On more careful examination the cut edge of a thin layer of fascia is found passing across the front of the prostate, about its lower third, and joining the two lateral reflexions where they are commencing to pass off the prostate (fig. 1, E).

We see, therefore, that the line of attachment of fascia passes along the side of the prostate at its junction with the bladder, and then turns vertically downwards on the front of the organ and is then continued across the middle line.

The anterior surface of the prostate between these two vertical lines of reflexion is covered in by a special layer of fascia to which I shall again refer.

The posterior surface of the prostate is covered in by a layer of fascia which splits off from the rectovesical fascia. This posterior layer is firmly attached along the line of the base of the prostate, and a further prolongation upwards from this line covers in the seminal vesicles and vasa deferentia and passes up over the ureters on the back of the bladder.

On examining a thick microtome section of the prostate and its surroundings at the level of the verumontanum, the rectovesical fascia is seen as a distinct layer (fig. 2). From the side of the rectum it passes forwards to the lateral surface of the prostate. On reaching the prostate it gives off a layer of fascia which may be traced on the posterior surface of that organ. It then passes forwards, covering the lateral and anterior surfaces of the prostate, but before reaching the middle line it passes outwards away from the gland. The space between the two reflected layers is covered in by tissue which differs in some particulars from the rest of the sheath and will be considered later.

These layers of rectovesical fascia are more easily distinguished by dissection than by microscopical section. In the section here described they are well seen, but in thin, lightly stained sections and in some prostates they are less readily followed.

Under the microscope the fascia consists of wavy fibres with a few nuclei. The fibres may be loosely set, but where the membrane is well defined they are closely packed.

Let us now return to the dissection of the sheath. If the levator ani be thrown back from the side of the prostate, the lateral surface of the sheath is exposed. This is readily picked up with forceps, and an incision may be made through it and a probe introduced between the fascia and the prostate (fig. 3). The sheath can now be stripped upwards towards the base. On reaching the base, however, the lobe of the prostate is adherent to the bladder, and any further stripping is prevented by the adhesion of the sheath along this line and by muscular fibres passing from the bladder wall into the prostate.

On stripping the fascia downwards, it peels off readily until the apex is almost reached. Here, coarse muscular fibres are found to lie between the sheath and the organ. These I shall show later to be striped muscle

fibres. Further stripping is prevented by the sheath being bound down around the apex On stripping the sheath backwards, the probe can be made to pass across the middle line, and with a little care the whole of the posterior surface of the gland can be bared of its sheath. The stripping on this aspect, as on the lateral surfaces, is only limited at the apex and at the base of the gland.

On stripping the sheath forwards, however, it is found that it is firmly

FIG. 3.—Lateral view of prostate and bladder.

A, Right lobe of prostate exposed. B, Bladder C, Line of attachment of rectovesical fascia. D, Line of reflexion of fascia from anterior surface of prostate. E, Levator ani muscle. F, Lateral layer of fascial sheath thrown back. A probe has been passed behind the prostate inside the sheath.

adherent along a broad vertical band at the front of the prostate. In order to turn up the sheath here it is necessary to cut through a layer of tissue: no line of separation can be produced by teasing.

I have had occasion to notice this portion of the sheath already, and shall now consider it a little more in detail. On the surface of the sheath this band is marked out on each side by the vertical lines of reflexion of the lateral layers of the sheath. Stoney[1] has pointed out that a portion

[1] *Jour. Anat. and Phys.*, vol. xxxviii., and also *Trans. Royal Acad. of Med. of Dublin*, 1904.

of the front of the prostate, where the visceral layer of fascia dips down, is covered by what is really the vesical reflexion of the fascia. This corresponds to the vertical band that I have just described as being adherent along the front of the prostate, although in my specimens the dipping downwards of the visceral layer of fascia on the front of the prostate appears to have been greater than in the description given by this observer, for he found the transverse attachment about the middle of the organ, while my dissections showed it lower down. In any case there is a strip in the front of the prostate from the base downwards for some distance which is bounded on either side by the reflexion of the lateral layers and below by the continuation of these across the middle line, which receives a covering different from the rest of the sheath.

By careful dissection the layer which corresponds to the vesical reflexion at the sides may be stripped off, and beneath it is found a band of tissue along the front of the prostate, firmly adherent to the organ. Microscopical sections made horizontally through the prostate at this level show that the fibres of this portion of the sheath are less regularly arranged than elsewhere, and that embedded in its substance are masses of fat and bands of non-striped muscle, and that the large venous channels on the front of the prostate lie among its fibres. Further, a thin layer of striped muscle fibres, to which I shall again refer, lies between this and the non-striped muscle of the gland stroma (fig. 2).

It will be seen, therefore, that the prostate lies in a sheath of fascia as an egg fills an egg-cup, and that it is loosely set in this cup of fascia except at the apex, where the fascia becomes incorporated with the striped muscle surrounding the urethra, and along the anterior surface.

The Relation of the Prostate to the Bladder Base.

The prostate is adherent at its base to the under surface of the bladder wall.

The area of the bladder base, which the organ underlies, surrounds the internal meatus in the form of an oval with the long axis transversely (fig. 4). In this specimen the organ extended backwards for half an inch, or to about the mid point of the trigone, and forwards for a quarter of an inch in front of the urethral opening. The greatest lateral extent was a line drawn from the meatus outwards and a little backwards, and measured nine-sixteenths of an inch on each side. This area does not, of course, map out the distribution of the gland tissue beneath the bladder base, which I shall later show does not advance in front of the urethra at this level, but it includes the base of the whole organ.

The figures vary a good deal in different subjects, but these may act as a rough indication of the area of bladder base which the prostate underlies.

If the mucous membrane be stripped from off the bladder base, the arrangement of the muscular bundles may be studied; and if we take advantage of the hypertrophy produced by urethral obstruction, the plan of the bladder base becomes still more evident.

The trigone of the bladder is not an artificial triangle indicated by arbitrary lines joining the ureters with each other and each with the urethral opening, but is mapped out by a distinct arrangement of muscular fibres.

FIG. 4.—Bladder base showing relation of base of prostate and seminal vesicles. [illegible]

A, Opening of urethra. B, B, Dotted line showing outline of upper surface of base of prostate. C, C, Openings of ureters. D, Interureteral bar. E, Dotted lines showing outlines of seminal vesicles.

Joining each ureteral opening is a muscular band known as Mercier's bar, evident in most bladders, but well raised and thick where urethral obstruction has led to hypertrophy.

From the ureter on each side a thick band of muscle passes down towards the urethra. These bands converge and unite so that this longitudinal muscle flows over the margin of the urethral opening in a continuous sheet.

In the centre of the triangle formed by these bands of muscle the fibres appear to interlace indiscriminately. On either side of, and behind, this muscular trigone the circular muscle of the bladder may be distinguished.

The further relations of the muscular bladder base to the base of the prostate are best studied by examining microtome sections.

In a sagittal section of the prostate through the urethra a thick layer of non-striped muscle is seen lying on the upper surface of the prostate (fig. 5). If the layers of the posterior bladder wall are traced towards the prostate, the outer longitudinal layer becomes lost upon the upper surface of the gland. The fibres gradually become incorporated with the non-striped muscle of the stroma of the organ. In front of the urethra the longitudinal layer of muscle approaches the anterior wall of the canal and becomes lost among the bundles of circular, non-striped muscle which surround it. The circular layer of bladder muscle, when traced from the posterior wall, approaches the

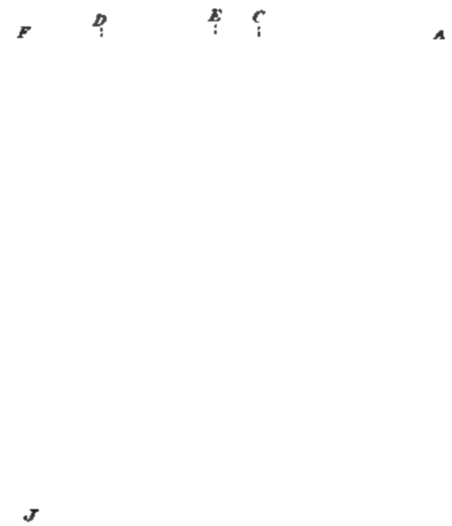


Fig. 5.—Medium sagittal section of prostate.

A, Circular layer of bladder muscle. B, Longitudinal layer of bladder muscle. C, Circular layer of trigone muscle. D, Unstriped sphincter of bladder. E, Longitudinal layer of trigone muscle. F, Urethra. G, Right seminal vesicle. H, Ejaculatory duct. J, Prostatic gland tissue. K, Striped muscle on front of prostate. L, Veins of prostatic plexus. M, Rectum. Q, Recto-urethral muscle.

base of the prostate, but, before reaching it, is replaced by a thicker layer of circular muscle the fibres of which are more closely set. From the anterior wall the circular layer passes quite down to the urethra and then blends with the circular muscle surrounding this tube.

When the muscle lying directly upon the prostatic base is examined, the arrangement is found to differ considerably from that of the bladder wall. A few fibres of the outer longitudinal layer of the posterior bladder wall are found intermingling with the muscular covering and with the non-striped muscle of the prostatic stroma. The circular layer of bladder muscle is, however, replaced by a layer of fibres which are more compactly

set, and, although circularly arranged, may be readily distinguished from those of the bladder wall. This layer, as it approaches the urethra, becomes thicker and forms a thick wedge behind the opening of the urethra. Hence it is continued downwards as a thin layer of circular muscle surrounding the urethra. In front of the urethra no such flat layer exists, but, as already stated, the circular bladder muscle is continued well up to the urethra. Along the front wall of the urethra, however, is a thick band of circular muscle, similar in its compact arrangement to that lying upon the base of the gland, and extending as a gradually thinning layer to the apex of the prostate.

Lying beneath the bladder mucous membrane over the flat wedge of circular muscle is a longitudinal layer of non-striped muscle. This commences about the posterior border of the compact circular layer, and passes forwards as far as the urethra, where it dips down to form the internal longitudinal layer of that canal. In front of the urethra these longitudinal fibres commence only a short way in front of the urethral opening, and pass backwards into the wall of the canal.

In sagittal sections more laterally placed (fig. 6), this circular and longitudinal arrangement of muscle on the bladder base maintains almost until the region of the ureteral opening is reached. In a section at the latter plane, one lobe of the prostate is seen cut vertically, and above it is a continuous layer of the outer longitudinal bladder muscle; above this, again, is the circular bladder muscle, on the surface of which is seen the commencement of the ureter. It will be recognised, therefore, that this layer of compact circular muscle and the longitudinal fibres lying upon it constitute the trigone of the bladder, and that the well-marked posterior margin of these forms the interureteral bar of Mercier.

What then constitutes the non-striped vesical sphincter? In my previous writings I have looked upon the whole of this flat layer of circular muscle as constituting the sphincter, and I find that this is in agreement with the view of Kalischer, as quoted by Frisch and Zuckerkandl in their work on Urology, published in 1904. Kalischer describes the sphincter as a fan-shaped muscle, the anterior part of which is spread out along the anterior surface of the prostatic urethra. Frisch and Zuckerkandl, however, regard only the wedge-shaped portion abutting upon the urethral orifice as the vesical sphincter. Their argument, that the rest of the circular trigone muscle must be at a disadvantage as regards sphincter action when flattened out in the distended bladder, seems a sensible one.

With the microscope the limits of the non-striped muscular prostatic stroma and of the overlying muscle of the trigone are by no means clearly

defined. The bundles of non-striped muscle intermingle, so that it is difficult to say along what line the prostatic stroma ceases and the muscle fibres of the bladder base commence. Further outwards, however, where the muscle of the trigone is replaced by the layers of the bladder wall, the

Fig. 6.—Series of sagittal sections of prostate and surroundings to follow fig. 5. These sections commence at the middle line and pass to the right.

A, Circular layer of bladder muscle. B, Longitudinal layer of bladder muscle. C, Circular layer of trigone muscle. D, Unstriped sphincter of bladder. E, Longitudinal layer of trigone muscle. G, Right seminal vesicle. J, Prostatic gland tissue. K, Striped muscle on front of prostate. M, Rectum. N, Vas deferens. O, Right ureter. P, Levator ani muscle.

definition is sharp, for the outer longitudinal layer of bladder muscle here shows no tendency to mingle with the fibres of the prostatic stroma.

The relations of the prostate to its sheath and to the base of the bladder have an important practical bearing on the surgery of the prostate.

The operation of perineal prostatectomy consists essentially in the exposure of the posterior surface of the prostatic sheath from the peri-

neum, in the incision of this fascia and stripping of it from off the prostate, and in the hemisection of the prostate and dissection of each half from the urethra and from the bladder base. It will be recognised, therefore, that the ready separation of the prostate on its posterior and lateral surfaces from its surrounding sheath of fascia is a point of special importance in this operation.

When the prostate is approached by the suprapubic route, the bladder base intervenes between the finger of the operator and the base of the prostate. Certain pathological changes take place, however, during the enlargement of the gland which overcome this difficulty. These changes I have fully discussed elsewhere, and they need not detain us here. I shall ask you to accept the statement that the enlarged prostate has pushed some part of its bulk through the lumen of the sphincter and dilated it so that only the mucous membrane of the bladder covers the intruding mass. By stripping off the mucous membrane the finger may be insinuated alongside or behind this mass through the lumen of the sphincter. The rest of the operation now consists in shelling the prostate out of its sheath. In doing so the upper end of the prostatic urethra, together with the remains of the longitudinal layer of trigone muscle, are torn through, the prostate is separated from the under surface of the bladder base, the ejaculatory ducts torn across, the adhesion along the anterior surface separated, and finally, the prostatic urethra severed about its junction with the membranous portion. The points of difficulty are just those that would be anticipated by a study of the connections of the normal gland.

THE STRIPED MUSCLE OF THE PROSTATE.

I have already referred to the non-striped sphincter of the urethra, the sphincter vesicæ, and it is necessary to consider briefly the striped muscle which is related to the prostate.

If the prostate be removed from the body, a ring of striped muscle will be found surrounding the urethra at its apex (fig. 1, H). This is a part of the compressor urethræ muscle. When traced upwards, it is found to cover the front of the apex of the prostate for a short distance, and here it is attached to the fascia on either side. Viewed from the surface of the sheath, the striped muscle appears to end here. Further dissection and microscopical sections show, however, that it dips in beneath the sheath at this point. I have already noted that, in stripping the sheath towards the apex, coarse muscular fibres were found between the prostate and the sheath. These fibres belong to the continuation of this muscle.

If horizontal sections of the prostate be made at right angles to the

urethra, what appears to be the apex of the organ consists of circular muscular fibres surrounding the urethra, and is therefore the upper portion of the membranous urethra. As the sections pass upward, the striped muscle is found to cover only the front of the urethra. At a slightly higher level the gland tissue begins to appear, and a wedge of non-striped muscle, the anterior commissure of the prostate, separates the striped muscle from the urethra. The striped muscle here lies between the anterior commissure and the anterior layer of the sheath. In this situation the layer of striped muscle passes upwards on the front of the prostate as far as the base of the gland.

A section of the prostate at the level of the verumontanum (fig. 2) shows a thin but definite layer of striped muscle lying on the front of the organ between it and the anterior layer of the sheath. Traced laterally, a few of these fibres stray among the non-striped fibres of the prostatic stroma, but the layer may be traced on each side on the surface of the capsule as far back as the level of the urethra. Here the fibres gradually diminish and disappear.

In a vertical sagittal section of the prostate this striped muscle may be traced upwards to the point where the circular bladder muscle joins the sphincter vesicæ in front of the base of the prostate (figs. 5, 6).

Henle described this muscle under the name "sphincter vesicæ externus." His description is not very full, but the sections of the prostate which he draws illustrate the layer. I have not observed, in my sections, the striped muscle fibres which this author traced along the posterior surface of the urethra as far as the verumontanum, and in my sections the layer passes higher on the anterior surface than Henle's drawings would indicate. This author did not of course discuss its relation to capsule and sheath.

The functional importance of this striped muscle as a sphincter of the urethra is difficult to estimate.

It appeared to me to be significant that in a specimen that I recently described,[1] where the walls of the "prostatic cavity" were examined two years after the operation of prostatectomy, the amount of these striped muscle fibres in the sheath seemed much in excess of what I had observed in the normal gland.

Of the surgical importance of the striped muscle surrounding the urethra at the apex of the gland I have no doubt. I do not intend to enter into the much discussed question as to whether the true sphincter of the bladder is the non-striped muscle at the internal meatus, or the striped muscle surrounding the urethra lower down, but I may state

[1] *Brit. Med. Jour.*, Oct. 7, 1905.

my opinion that after the operation of suprapubic prostatectomy, the striped muscle performs a very important part in retaining the urine. In some of the patients on whom I had performed prostatectomy, I passed the fine catheter of a Guyon's syringe into the cavity left by removal of the prostate. As soon as the bulbous end of the catheter passed the constrictor urethræ into the "prostatic cavity," the urine began to drip away. This would show that after suprapubic prostatectomy the striped sphincter takes on, at least, the major part of the retentive function.[1]

In my opinion this is a weighty argument against the perineal drainage of the cavity after suprapubic prostatectomy, as has been suggested; and further, this explains a fact, which I think is undoubted, that the control of the urine after prostatectomy is more often imperfect after the perineal operation than after the suprapubic.

The Prostatic Plexus.

The relation of the plexus of veins to the prostate is a subject of vital surgical interest.

The dorsal vein of the penis passes backwards under the pubic arch to disappear in the tissues covering the front of the prostate, and its further course is best studied by removing the pelvic organs from the body. It is then found that this vein has passed on singly or divided in two, and the openings of these channels are found in the front of the prostate a little way above the apex of the organ, just below the line along which the visceral layer of pelvic fascia meets that organ. On slitting up the veins a number of channels are found lying on the front of the prostate These pass upwards towards the base of the organ, communicating with each other by lateral branches.

Arrived at the base, a number of smaller venous channels pass outwards on each side around the junction of the bladder and prostate, and thus form a figure resembling somewhat the letter Y, the vertical stem of which lies upon the anterior surface of the prostate, while the arms of the Y embrace the junction of bladder and prostate on each side (figs. 7, 8). Thence they

[1] This was not, however, invariably the case, for the "prostatic cavity" in some of these cases was empty when the bladder was full, and, moreover, no urine was left behind in this cavity immediately after the bladder had been voluntarily emptied. One may conclude that in these cases the bladder sphincter had regained its function, and also that there was sufficient contractile power in the wall of the prostatic cavity to empty it completely of urine. The latter function may perhaps be referred to the striped muscle fibres which I have described in the wall of the cavity.

pass upwards and outwards to join the internal iliac veins. The vertical stem of the Y represents the prostatic plexus, while the arms are the main channels of the vesico-prostatic plexuses. Dissection of the veins of the prostatic plexus is a matter of some difficulty, for they are firmly embedded in the tissue forming the anterior layer of the prostatic sheath.

The number and arrangement of these veins varied a good deal in the specimens I dissected. Three or four large intercommunicating channels were a common occurrence. At the base a transverse communication was usually observed.

The lateral extent of the sinuses seldom passed much beyond the

C

FIG. 7.—Prostatic plexus of veins.

A, Anterior surface of prostate. B, Bladder. C, Termination of dorsal vein of penis. D, Prostatic plexus. E, E, Vesico-prostatic plexuses. The dotted line shows line of attachment of fascia.

vertical line of reflexion of the sheath on the front of the prostate. The veins were therefore, for the most part, embedded in the thick compact anterior layer of the sheath, and the lateral layers of the sheath might be reflected from off the prostate without damaging any vein of considerable size, while the posterior layer of the sheath was quite free from veins of any importance. At the apex of the prostate a large vein passed outwards and backwards on each side.

On making horizontal sections through the prostate, these veins were seen to be embedded among the tissues forming the anterior layer of the sheath, and between this part of the sheath and the stroma of the prostate was the thin layer of striped muscle which has already claimed attention.

The arms of the Y forming the vesico-prostatic plexuses consisted of many veins of much smaller calibre than those of the ascending stem.

These might be seen without dissection lying upon the surface of the bladder, just above the attachment of the rectovesical fascia, and receiving the veins from the wall of the bladder. Larger veins were placed more deeply in the angle between the prostate and the bladder, and these appeared to be the direct continuation of the sinuses of the prostatic plexus. Veins passed upwards into those from the lobes of the prostate, but the greater number of these prostatic veins appeared to pass out to join the plexus at the point of junction of the posterior and lateral surfaces and the

FIG. 8.—Prostatic plexus of veins, side view.

A, Right lobe of prostate. B, Bladder. D, Prostatic plexus on anterior surface of prostate. E, Vesico-prostatic plexus. F, End of right seminal vesicle. G, Vas deferens. H, Right ureter.

base. Towards the posterior part of the prostate these plexuses came into relation with the end of the seminal vesicles, the vasa deferentia, and the lower ends of the ureters, and received veins surrounding these structures (fig. 8).

Some variations were found in different subjects. Sometimes the vertical stem of the Y was short, and the arms began to spread outwards before reaching the base of the prostate. The veins were thus spread out over a greater surface of the front of the prostate. The prostate varies a good deal in size within normal limits, and it is in the longer prostates that the arrangement described is best seen. In small, short, poorly developed glands the vertical portion of the plexus is much shortened.

It will be seen, therefore, that the prostatic plexus comes into relation

with the prostate only along the anterior surface of that organ, while the vesico-prostatic plexus lies above the level of the prostate. Further, the prostatic plexus is embedded between the fibres of the thick anterior layer of the sheath, and does not lie between the sheath and the capsule. This view of the prostatic plexus differs very materially from the commonly accepted descriptions. I had already made my dissections and notes upon these veins when Dr Proust of Paris drew my attention to his thesis of 1900, in which he had pointed out that the veins lay between the layers of the sheath and not between the sheath and capsule.[1]

The surgical importance of these observations is obvious. In perineal prostatectomy the posterior surface of the prostatic sheath is exposed and incised, and on this aspect no veins of any importance are encountered.

In suprapubic prostatectomy the danger of hæmorrhage from the prostatic plexus was, until a comparatively recent date, held to be imminent. It was said, and, according to the usually accepted description of the course and position of the prostatic plexus, with some logic, that if the entire prostate were removed, the prostatic veins lying between the capsule and the sheath must be torn through and lead to fatal hæmorrhage. When it is realised that these venous channels lie between the layers of the sheath on the front of the prostate, and do not course between the capsule and the sheath, and further, that at the side of the organ they are high up out of danger, the feasibility of such a complete operation becomes evident.

The Prostatic Urethra.

I shall only touch upon one point in regard to the prostatic urethra, for I have already discussed the non-striped and striped muscle sphincters which relate to this part of the canal.

Examination of sagittal and horizontal sections through the prostate has given me the impression that this part of the urethra is by no means the straight vertical tube it is commonly considered. A section in the long axis of the tube shows that the first part of the tube, from the bladder opening to the verumontanum, is straight and vertical. At the verumontanum, however, the urethra begins to curve forwards, and the remaining part of its course is as much forwards as downwards.

I have had no opportunity of examining frozen sections, so that some fallacy may underlie this observation, but the curve forwards of the lower part of the prostatic urethra was so constant in different subjects, that the description is probably reliable. Horizontal sections of the prostate show

[1] This author quotes, in his work on prostatectomy, published in 1904, a description of the course of these veins by Ziegler, which is somewhat similar to that I have given.

that at the entrance of the bladder the urethra lies upon the same plane as the anterior borders of the lateral lobes. From this level to the verumontanum it gradually sinks backwards in relation to the glandular tissue, so that at the latter level it is midway between the anterior and the posterior surfaces of the organ. From this point it passes more and more towards the front of the organ as the gland tubules disappear.

Let me say one word in regard to the clinical anatomy of the prostatic urethra. I have previously shown[1] that in the majority of cases of suprapubic prostatectomy the prostatic urethra is removed, with the exception of a small strip which represents the posterior wall of the canal from the membranous urethra up to the verumontanum, and this is left adherent to the sheath.

I have examined many specimens since I made the statement, and I am convinced that this is a rule from which there are but few exceptions.

The accepted theory of the act of micturition is that a few drops of urine are forced into the sensitive prostatic urethra from the distended bladder, and that from this mucous membrane the whole reflex of micturition is initiated.

If the prostatic urethra is removed, whence comes the sensation which initiates the reflex?

I have questioned patients after the operation as to their sensations, and they invariably state that the desire to micturate differs in no way from that which they experienced before the urethra was mutilated.

Is it possible that the sensation originates in the strip of mucous membrane that is left behind? I hardly think that this is likely, for in some cases this part of the urethral wall is removed also, and the patients suffer from no disability in regard to micturition. I think it is probable that we shall have to rearrange our ideas in regard to the reflex act of micturition if these observations are correct.

The Arrangement of the Gland Tissue.

The gland tubules lie embedded in a densely woven stroma of non-striped muscle. There is no very distinct circular arrangement of the fibres of the stroma around the individual tubules. At the surface of the organ there is an area of stroma where no gland tubules can be seen (fig. 2). This area varies in breadth; in some parts the tubules approach nearly to the surface, in others they lie well back so as to leave a broad rim unoccupied. The fibres at this part are more circular in their arrangement than they are

[1] *Medico-Chirurgical Transactions*, London, 1904; *Archives of the Middlesex Hospital*, vol. iv., 1905; *British Medical Journal*, July 9, 1904.

elsewhere in the organ. This rim of stroma is the true capsule of the prostate. It cannot be dissected away without injury to the prostatic tubules, for it is a part of the stroma and intimately connected with the intertubular stroma. I have not observed the bands of tissue which are said to pass inwards from the capsule towards the urethra. The tubules are merely set in a meshwork of stroma, and are much less regular in their arrangement than one would expect from some descriptions.

The distribution of gland tissue varies at different levels. A section at the apex of the organ shows the urethra surrounded by striped muscle. At a slightly higher level the gland tissue begins to appear, and is found in small amount on each side of the urethra, while a few tubules may be found behind that tube. Still higher up the lateral masses of gland tissue increase in dimensions, and here a thin band of gland tissue unites the lateral lobes behind the urethra.

At the level of the verumontanum the gland is in the form of two masses which lie on either side of the urethra, and a broad tract of gland tissue unites these behind the canal (fig. 2). Here the ejaculatory ducts and sinus pocularis begin to pass backwards and indent the uniting band of gland tissue. Horizontal sections above this level show the ejaculatory ducts and a surrounding sheath of non-striped muscle passing backwards, and another band of gland tissue appears between them and the urethra, and this increases so that at the upper limit of the prostate the gland tissue is in the form of a horse-shoe formed by the lateral lobes on either side, and this posterior band connecting them behind the urethra.

The wedge of gland tissue which lies between the receding ejaculatory ducts and the urethra, and forms the connecting link between the upper extremities of the lateral lobes, corresponds to the median lobe of Sir Everard Home. There was no separation of this portion into a special lobe in my specimens.

In front of the urethra, along the whole length of the prostate, is a vertical wedge of non-striped muscle tissue. This anterior commissure separates the two lateral lobes. It was present in all the specimens I examined, although it varied a good deal in breadth, and in one subject the lateral lobes approached each other so closely in front of the urethra that the commissure was scarcely demonstrable at the level of the verumontanum.

In most specimens a few small gland tubules were embedded in the anterior commissure, but it was difficult to judge whether these opened upon the anterior wall of the urethra or were merely prolongations of tubules from the lateral lobes.

THE SEMINAL VESICLES.

I shall close with a brief reference to the position and relations of the seminal vesicles. I confess that on commencing clinical work I was firmly imbued with the idea that the seminal vesicles passed upwards and outwards along the posterior wall of the bladder, diverging slightly in their course, and that only a small part of these organs was palpable by the finger in the rectum, the remaining half or more being out of reach. This impression was gained from my anatomical reading, and I was therefore surprised to find that the diseased seminal vesicle was well within the reach of my finger to the whole of its extent. This led me to examine these organs when I was dissecting the prostate, and I found that my clinical observations had not led me astray. In my dissections the seminal vesicles lay along the upper border of the prostate and passed out in a transverse direction on each side for a variable distance beyond the lobes of that organ (fig. 9). The outer end of the vesicles turned slightly upwards as they passed round the sides of the bladder. Above each vesicle was the corresponding vas deferens, the ampulla of which rested on the border and upper surface of the vesicle. Only at the outer end of the seminal vesicle did the duct curve upwards to cross the lower end of the ureter. The ureters disappeared beneath the vas deferens and the outer end of the seminal vesicle, but could sometimes be dissected just as they entered the bladder wall on the inner side of the vasa deferentia.

The vesicles and vasa were invariably bound down to the bladder wall by a firm and well-defined layer of fascia which, when dissected, passed down to be attached along the margin of the base of the prostate.

The relation of the peritoneum to these organs will be seen by referring to the accompanying drawing. The peritoneum of the rectovesical pouch descends so as to cover the vasa deferentia, and about one-half of the breadth of the vesicle. The lateral extent of this pouch gives a peritoneal covering to about one-half of the length of the vesicle on each side.

The clinical importance of this is obvious, for it is realised that the seminal vesicle is well within the reach of a finger in the rectum.

I do not doubt that this relation of the vesicles is familiar to many or all of you, but it has not yet found its way into anatomical text-books, and I take this opportunity of drawing your attention to it.

The relation of the vesicles to the bladder base is of considerable importance to the surgeon, and especially where the cystoscope is used.

I have mapped out on the base of the bladder the outlines of the underlying prostate and seminal vesicles. You will see that the vesicles underlie

the posterior part of the trigone, and extend beyond it posteriorly and laterally.

FIG. 9.—Dissection of posterior surface of bladder and prostate, showing structures in relation to the anterior wall of the rectum. ½.

A, Prostate. B, Bladder. C, Seminal vesicles. D, Ampulla of vas deferens. E, Ureter. F, Constrictor urethræ surrounding membranous urethra. The dotted line shows relation of the peritoneal pouch of Douglas to these structures.

(The drawing shows the ureters too high up. The upper border of the prostate is horizontal and not rounded off as here depicted.)

The outline, more accurately stated, commences at the centre of the trigone half an inch behind the internal meatus and passes outwards, sweeping round the opening of the ureter about a quarter or half an inch

from the opening, and then passing inwards behind the inter-ureteral bar of Mercier to the middle line, where it dips down as far as the posterior margin of that bar. If a similar line be drawn on the other side, the vesicles will be mapped out. From tip to tip the vesicles measured about two inches across (one- and fifteen-sixteenths) in this specimen. From the internal meatus to each tip one and a half inches.

These numbers are merely tentative, they require to be corroborated by a series of observations before being taken as the average measurements.

You will realise how difficult is the accurate palpation of the trigone of the bladder by the finger in the rectum when the prostate underlies the anterior half and the seminal vesicles the posterior half.

I must tender my grateful thanks to Dr R. A. Young of the Middlesex Hospital, and to Mr J. R. Lunn of the Marylebone Infirmary, for supplying me with material for dissection; and also to Mr A. G. R. Foulerton for facilities for carrying out the work in the clinical laboratories of the Middlesex Hospital. I would further express my thanks to Mr G. L. Cheatle, in whose laboratory were cut some of the sections from which fig. 6 was constructed.

ON THE ANATOMY OF THE CALAMUS REGION IN THE HUMAN BULB; WITH AN ACCOUNT OF A HITHERTO UNDESCRIBED "NUCLEUS POSTREMUS." By J. T. WILSON, *Professor of Anatomy in the University of Sydney, N.S.W.*

PART I.

§ I. COMMENTARY UPON CURRENT DESCRIPTIONS OF THE CALAMUS SCRIPTORIUS REGION.

THE current descriptions of the anatomical characters of the region of the calamus scriptorius are neither uniform nor wholly consistent with one another. There is also a notable lack of exact information in regard to the finer structural details. When one turns to the standard text-books of anatomy, or even to the now rather numerous special treatises on neurology, in search of an explanation of the precise manner in which the central canal of the medulla oblongata actually expands into the cavity of the fourth ventricle, only vague and general statements are, for the most part, met with. The process of opening-out is apparently assumed to be a quite simple and self-evident one. Whenever the limits of more general statement are overstepped, marked discrepancies between different descriptions appear. It may be presumed that myriads of microscopical sections from this region have been cut, stained, and mounted, yet I am not aware of a single text-book figure which adequately illustrates the transitional structural characters met with in passing from central canal to fourth ventricle. The various figures which purport to do so—few as they are in number—are extraordinarily divergent in appearance.

Two or three instances, only, need be here referred to in illustration of these statements.

In *Quain's Anatomy* (1893, p. 47) we read only that "the central canal of the cord, after becoming somewhat enlarged and cleft-like, opens out superiorly. The opening-out seems as if affected by the divergence of the nuclei funiculi graciles et cuneati on either side at an acute angle." No illustrative figure is given of a section at the calamus, and the two figures illustrating the structure below the calamus (figs. 43 and 45, after Schwalbe and Lockhart-Clarke respectively) are largely diagrammatical.

Even v. Koelliker (1896), in his splendidly illustrated *Handbuch*, figures

no section at the apex of the calamus, nor any section showing the actual manner of transition into the fourth ventricle.

Edinger (1900) describes (p. 387) the dorsal columns as diverging from one another, "thus exposing the posterior grey commissure in the angle between them. At this level the central canal expands into the fourth ventricle; its covering thinning and expanding to form the roof of the latter." The illustrative figures are professedly schematic, and do not aid in elucidating the finer details of the transition.

A like criticism may be passed upon Van Gehuchten's general description and figures (1900, pp. 16, 18–19, figs 341 and 342). This author holds, however, that the essential factor in the expansion is to be recognised, not in the divergence of the dorsal columns from one another, but in their actual termination here as such. In another series of figures this author further illustrates the transition-region of the neural canal in the rabbit. In these figures there appear several features, not specially commented upon in the text, to which reference will be made later on.

In the macroscopical part of his description of the encephalon, Ziehen (1899) makes reference to the manner of opening-out of the central canal. His work is illustrated by low-power photographs, but in the absence, thus far, of the microscopical section of his work, a representation of the finer details could not well be looked for. His description (p. 387) is to the effect that at the "apertura canalis centralis," through which the central canal opens out into the cavity of the fourth ventricle, "the roof of the central canal disappears relatively abruptly, giving the impression that the dorsal columns which had constituted the roof of the spinal medulla, and of the caudal segment of the medulla oblongata, suddenly diverged, ... thus leading to the abrupt widening of the central canal into the fourth ventricle." In the chapter on macroscopical *sectional* anatomy, nothing is added to the conception thus stated. A photomicrograph is, however, reproduced in fig. 176, which purports to represent a section through the region of the opening of the central canal into the fourth ventricle. The section of the widening canal is here represented to be a small, equilaterally triangular opening overhung by a slender bridge of tissue which is stated to be the obex. I cannot avoid the conviction that Ziehen has misinterpreted the section represented by the photomicrograph. It assuredly does *not* correspond to a transverse section through the region of the apex of the calamus scriptorius, or of the genuine "Bereich der Eröffnung des Centralkanals." Both in general contour and in various individual structural features the section answers to a transverse plane above the level indicated, *i.e.* to a plane in which the lumen of the neural canal has already expanded into a widely open ventricular cavity.

Neither in any other published figure of the sectional anatomy of this region that I have been able to discover, nor in a single one of eight series of sections which I have myself specially examined with reference to this point, does the sectional contour of the medulla oblongata, at the plane of the opening-out of the central canal, at all resemble the form shown in Ziehen's figure; but, on the other hand, the latter entirely corresponds with the general contour of sections taken at a higher level than that ascribed to the section. The central grey matter is not distributed as around a central canal about to open, but is already spread out dorso-laterally and superficially, as upon the floor of a fourth ventricle. Again, the restiform bodies have, in the section under notice, already been largely constituted as lateral prominences widely remote from one another—a relationship which is utterly inconsistent with the notion that the section is from the plane of the inferior angle of the fossa rhomboidalis. And, again, the depressed dorsal contour-line of the section shows traces of the characteristic modelling of the ventricular floor. I am confident that the genuine thin ventricular roof had simply been lost in the preparation of the section. (The pia mater is defective around the entire contour of the preparation.) Traces of the original site of attachment of the absent ventricular roof are, indeed, actually visible in the photographic illustration, especially on the left side and a considerable distance out, in fact just lateral to the reference line lettered *Trs.* It is easy to recognise the corresponding place on the right side, though the roof-attachment has there left practically no vestige. An inspection of fig. 6 (p. 237), which is a reproduction of a photomicrograph of a cross-section through an adult human medulla oblongata, will suffice to show its essential correspondence with Ziehen's fig. 176. It represents a section taken considerably above the level of the opening-out of the central canal. In so far as it differs from Ziehen's figure, it does so in virtue of the fact that it represents a lower, or *more caudal*, plane than that really represented by the former. Yet its shows the neural canal as an already widely open ventricular cavity.

Ziehen has doubtless been misled by his interpretation of the slender band of tissue, which is seen in his figure bridging over the opening of his "central canal," as an "obex." This latter it certainly is not. Its probable correct interpretation will appear further on in this paper. But in refusing the name of "obex" to the bridge of tissue which appears in Ziehen's figure, I am not denying that the small triangular space which Ziehen interprets as "apertura canalis centralis" is really a passage prolonged from the central canal of the medulla oblongata. But I do maintain that the opening of this passage into the cavity of the ventricle does not represent, and is not situated in the plane of, the true morphological expansion of the central

canal into the cavity of the rhombencephalon; nor does it coincide with the apex of the calamus scriptorius. The latter point is situated some distance caudal of the plane of the section figured by Ziehen.

The error in Ziehen's interpretation could not have arisen had the ventricular roof been preserved in the sections figured. The fact is, that no observations on the detailed anatomy of this region can nowadays be regarded as adequate and conclusive unless carried out with the aid of methods which avoid the destruction, or the extreme displacement, of the pia-ependyma. It is unfortunate that, in those chapters of an important treatise which deal explicitly with the macroscopical anatomy of the rhombencephalon, there should be no attempt to reproduce, in the sectional figures, the important relations of the ventricular roof.

So far as I am aware, the only text-book in which there is to be found anything like an adequate discussion of the mode of opening-out of the central canal into the fourth ventricle, is Henle's *Nervenlehre* (1873). The methods of preparation at Henle's command thirty years ago were insufficient to the complete preservation of the normal relations of the pia and the intimately related ependyma. Consequently Henle's conception of the roof of the fourth ventricle was an imperfect one. The cavity itself is regarded as a wide expansion of the *dorsal median fissure* continued up from the caudal segment of the medulla oblongata. Into this fissure, either just before or at the point of its lateral expansion to form the ventricle, the central canal of the lower part of the medulla oblongata is represented as opening.

An imperfect conception of this kind does, of course, necessarily vitiate Henle's account of the anatomy of the region. Nevertheless, in spite of the limitation and distortion thus imposed, Henle's descriptions are more objective and more complete in detail than those now ordinarily current. Nor is it difficult to interpret them into more modern language and to read them in the light of more recent morphological and developmental conceptions.

§ II Special Commentary upon Henle's Classification of Variations in the Structural Characters of the Ventricular Opening of the Central Canal of the Bulb.

A closer examination of Henle's account may serve a useful purpose at this juncture. Two separate categories of cases were recognised by Henle as exhibiting different methods of opening of the central canal of the bulb. (1) One category embraces those cases in which the canal opens dorsally into the widening "posterior median fissure," between the anterior ends of

the two clavæ; (2) another includes those cases in which it opens upon the floor of the fourth ventricle, close in front of the ends of the clavæ.

Of the first class of cases he says that the bridge of tissue, separating the canal from the bottom of the posterior median fissure, gradually thins out and disappears. But two varieties occur under this category. In one variety (*a*) the central canal increases only slightly in sagittal extent before it opens into the gradually deepening posterior median sulcus (*cf.* his fig. 144). In some of these cases, indeed, he says that the central canal is obliterated almost up to the point where the opening occurs. In the other variety (*b*) the median fissure remains shallow, becoming even shallower as it is traced upwards, whilst the central canal increases in its sagittal diameter and the thin partition between it and the shallow median sulcus is at last broken through. He figures a central canal exhibiting these latter characteristics in his fig. 134.

There can be no doubt that Henle's distinction between the conditions illustrated by his two figs. 134 and 144 is based upon a misapprehension of the nature of the deep cleft shown in fig. 144. The latter figure is imperfect, in its lack of any indication of the line of attachment of the ependymal roof of the neural cavity. Henle was certainly mistaken in regarding the major portion of the cleft as "posterior median fissure." The sulci in the lateral walls are undoubtedly intraventricular, or at least intramedullary. The entire loss of the pia mater—a loss or displacement which the less perfect technique of Henle's day rendered practically unavoidable—had involved the destruction of an ependymal roof which was certainly originally present, covering over the cleft-like cavity dorsally. The condition illustrated in Henle's fig. 144 is, in fact, quite easily derivable from that shown in his fig. 134 by a process of slight lateral expansion of the cavity, accompanied by a thin ependymal expansion of the roof-plate, traces of whose attachment ought to be visible dorsally in such a preparation as that represented in fig. 144.[1]

The second class of cases recognised by Henle consists of those in which the central canal is prolonged some distance in front of the clavæ before it opens in the median sulcus of the floor of the ventricle. His fig. 145 illustrates a section in such a case, showing a small canal prolonged forwards between the hypoglossal nuclei, beneath the floor of an already open ventricle. Upon this he remarks that, "Es ist die graue, die beiden Accessoriuskerne verbindende Substanz, die der Centralcanal durchbricht, und diese breitete sich von der Furche her als dünne Rindenschichte nach

[1] Streeter (1903) seems to have dropped into the same error when he says (p. 304), "In fig. 3 the posterior longitudinal fissure has become continuous with the central canal, but is bridged over dorsally by the obex."

beiden Seiten über die am Boden Ventrikels befindlichen Gebilde aus. Was man als Obex beschreibt, der zwischen den Clavae sichtbare Rand der hinteren Wand des Centralcanals, hat demnach ebenfalls verscheidene Structur, besteht aus weisser oder grauer Substanz." Thus it is plain that Henle's lack of exact knowledge of the ependymal roof-arrangements of the fourth ventricle led him to confuse, under the one term of "obex," two quite different structural masses. As we shall presently recognise, the obex has nothing whatever in common with the bridge of tissue roofing over the terminal part of such a canal as is figured by Henle in his fig. 145, opening in the median sulcus of the floor of the fourth ventricle. It is this identical confusion that Ziehen has perpetuated, being misled by a specimen possessing characters essentially similar to those exhibited by Henle's second category of cases. Unlike Henle, however, Ziehen apparently does not distinguish this form from that of the (more typical) class of cases in which a cleft-like "apertura canalis centralis" debouches into the ventricle under the cover of a true obex. It is a true obex that Ziehen describes in his very clear account of the "obex" on pp. 400–401. It is a structure entirely different from this that he labels and describes as "obex" in his fig. 176 and its text explanation.

Some further discussion of the nature and relations of the obex may therefore be regarded as not wholly superfluous in this connection.

§ III. Discussion of the Nature of the Obex, and of its Relations to the Ventricular Roof and the Foramen of Magendie.

In Retzius's great work, *Das Menschenhirn* (1896), we find a thoroughly objective description of the fourth ventricle, abundantly illustrated by figures of the highest excellence. Here the constitution of the roof of the fourth ventricle is accurately set forth and portrayed. Amongst other points, the genuineness of the foramen of Magendie as a normal aperture is anew substantiated. The obex is defined as a short arcuate band of brain-substance stretched across in front of the two clavæ. It is stated to be a quite inconsiderable structure, lacking in the majority of cases, and, even where present, exhibiting very various degrees of development. When it is present, it is found at the hinder margin of the foramen of Magendie. In the majority of cases, however, the hinder border of this foramen is stated to be formed by a sharply defined pial fold, immediately in front of which the ventricular ependyma begins. In most cases in which an obvious obex is present, a close inspection reveals, behind it, a similar pial fold. Retzius holds this latter to be the genuine posterior margin of the foramen of Magendie, and not the obex itself.

The inconstancy in character of the obex has been recognised by anatomists generally. Upon the question of its relation to the roof of the ventricle in general, and to the foramen of Magendie in particular, further light has, I think, been shed by the investigations of Blake. In 1898 this author published a paper dealing with the anatomy and comparative anatomy of the roof and lateral recesses of the fourth ventricle. Amongst Blake's conclusions are the following:—"(4) That in mammalia and aves a caudal protrusion of the roof of the fourth ventricle is formed at some stage in their embryonic life. (5) That in mammalia there is a tendency to the absorption of the ventricular epithelium unless it is supported by nervous matter or by the pia of neighbouring structures. (6) That in man the caudal protrusion becomes lost, giving rise to a metapore (foramen Magendii). (7) That in all Anthropoideæ there is generally a similar metapore formation. (9) That in the lower mammalia the caudal protrusion, as a rule, remains closed."

From the facts and observations detailed in Blake's paper, it seems tolerably well established that the foramen of Magendie, so far from being an artefact, is really the imperfect representative of an epithelial evagination of the cavity of the rhombencephalon. The epithelial parietes of the body or fundus of this evagination seem largely to disappear in man and in the higher mammalia; so that its cavity becomes continuous with the cavity of the subarachnoid space. The remark of Blake that the metapore, or foramen of Magendie, is "essentially not an aperture in the roof, but rather the disappearance of the end of a structure," is perhaps infelicitous, but it is nevertheless quite intelligible when read in connection with his drawings, notably his fig. 26. In lower mammalia the body of the caudal protrusion seems to retain its integrity, and persists as a saccular evagination lying on the dorsal aspect of the caudal segment of the bulb. The latter condition is illustrated in Blake's figs. 24 and 25 of sagittal sections from Didelphys and Canis respectively. They are to be compared with his fig. 26 of a sagittal section through the corresponding region of the human fœtus.

It is true that in the great majority of instances only relics of the walls of the original saccular protrusion are preserved in the adult human subject. I have, however, observed one or two cases in which the preservation of a very considerable proportion of the original parietes of the evaginated saccular protrusion could easily be verified. But in any case, if an obex is present, the free anterior margin of this structure does not represent the line of attachment of the ventricular roof. The ependyma lining the widening ventricular cavity, over whose caudal angle the obex is situated, is reflected from the inferior surface, around the anterior free concave

margin, and over the entire dorsal aspect of the obex, to leave it finally by reflection along the line of the pial fold noted and figured by Retzius as lying behind the obex. It is with this fold, and not, as often represented, with the obex itself, that the more or less imperfect pia-ependymal roof of the hinder segment of the rhombencephalon is continuous.

Blake, in his fig. 26, shows a sagittal section of the bulb of a human fœtus in which the obex appears as a shelf-like projection forwards towards the foramen of Magendie. It is obviously strictly intraventricular, inasmuch as it forms part of the floor of a caudal-dorsal prolongation of the ventricular cavity, and at the same time the roof of a small "supra-postremal" recess (*v. infra*, p. 46) of the ventricle. This recess intervenes between the obex above, and the dorsal aspect of what Blake regards as a median fusion of the "primary rhomboidal lips" of His. This I shall show later on to be an error. The coalescence which Blake's figure shows is "interpostremal." But, as we shall see, the postremal masses do not represent the "primary rhomboidal lips."

The position of Retzius's "pial fold" is clear from Blake's fig. 26. In the light of Blake's investigations, however, it must be regarded as not pial merely, but as pia-ependymal. And if we regard it, with Retzius, as forming the genuine hinder margin of the foramen of Magendie, we must further recognise that it constitutes the dorsal reflection of the pia-ependymal roof of the fourth ventricle into the parietes of the irregular and largely extra-neural space which, in the human adult, represents Blake's "caudal protrusion." It results from this that the true obex, when present, is in a sense intraventricular, as Blake insists, and as Retzius implies. It is, nevertheless, in origin and development, a roof-structure, and its plane represents that of the primitive roof-plate of this region of the neural canal. It is, in fact, a thickened part of the roof-plate of the canal of the myelencephalon, which, in the early embryo, lies immediately caudal of the thinned and expanded roof of the rhombencephalon. In accordance with this, Blake regards it as representing the continuation, across the median plane, of the secondary rhomboidal lips described by His in connection with the embryonic rhombencephalon (*cf.* His (1891)). The saccular "caudal protrusion" or evagination involves the region of the thin roof of the rhombencephalon lying immediately in front of the median-dorsal point of continuity of the secondary rhomboidal lips. According as this latter point does, or does not, become the site of medullary thickening, a genuine obex will be present or absent. In the latter case, however, it will be represented by unthickened ependyma supported by pial investment.

§ IV. Description of Cases showing Nature and Variations of Obex. Its Definition as Roof-plate.

The prevalent types of arrangement as regards the obex-region in the human adult may here be reviewed and illustrated as follows:—

Fig. 7, A and B (p. 237), represents a stereophotograph[1] of the dorsal aspect of a portion of the medulla oblongata of a human adult. It includes the caudal part of the fourth ventricle, from which the pia-ependymal roof (tela choroidea inf.), limiting a foramen of Magendie, was removed. A true "intraventricular" obex is here visible. Its entire dorsal surface is clothed by ependymal epithelium which extends outwards on each side as far as the attached margin of the obex, and backwards into the angular recess dorsal to it, between the diverging clavæ. Along these limits the ependymal epithelium is reflected into the thin parietes of the spacious (subarachnoid) representative of Blake's "caudal protrusion."

Fig. 8 (p. 238) represents a photomicrograph of part of a transverse section through the same specimen, shown in surface-view in fig. 7, at the plane of the obex. The latter appears as a marked thickening of the narrow roof of the neural canal, part of which is here visible as a deep and narrow cleft. But, as already stated, the *dorsal* aspect of this thickened roof or obex is clothed by ependymal epithelium. This is seen to be reflected, at the sides of the structure, in a dorsal direction, in which it is traceable for a considerable distance. Thus the surface depression, dorsal to the obex, is in reality part of a space or cavity which is continuous, in front of the obex, with the cavity of the fourth ventricle, and is thus, at least in part, a ventricular evagination. The membranous parietes of this space were necessarily largely destroyed in preparing the specimen for the stereophotograph reproduced in fig. 7.

A condition practically identical with that just described is illustrated in fig. 9 (p. 238), from a series of sections through the same region in another specimen of an adult human medulla oblongata, to which, later on, further reference will be made. Here again the true obex appears as a somewhat vaulted roof, covering over the cleft-like neural canal. Indenting, somewhat asymmetrically, its dorsal surface, is a V-shaped depression, from either side of whose opening the pia is reflected in a lateral direction. The concavity of this depression is lined by a layer of ependymal epithelium, which in some sections is imperfect and not easily demonstrated, but is

[1] It is important that the stereoscope should be employed in the examination of the stereographic figures illustrating this paper, if the full realistic effect of the illustrations is to be available. Any ordinary stereoscope with detachable cardholder may be used, the latter being, of course, removed.

readily evident in others. This V-shaped depression is open above, and forms part of an obvious backward extension of the cavity of the fourth ventricle, above the level of the obex. The thin membranous roof (tela choroidea inferior) of the ventricle, with portions of the choroid plexus, are visible dorsally; together with a more solid mass of tissue which, on examination of the series of sections, is found to be a part of the medullary "ponticulus" of one side of the ventricular roof. The section figured passes through the obex a short distance (0·06 mm.) caudal to its free anterior border. Fig. 10 (p. 238) shows a section through the obex in the same specimen a short distance further back, at the caudal limit of the free intraventricular part of its dorsal surface; *i.e.* across the plane at which the pia-ependyma begins to be reflected from the dorsal surface of the obex. At this limit, therefore, the ependymal lining of the dorsal caudal extension of the ventricle fails to reach the dorsal surface of the obex. Fig. 11 (p. 238) illustrates a section a short distance in front of the anterior edge of the obex in the same specimen. On the right of the figure the inflexed lateral part of the obex still persists, whilst on the left, owing perhaps to a slight obliquity in the plane of section, all trace of the obex, as such, has vanished, through its continuation into the tænia ventriculi.

A structural arrangement, differing somewhat widely from that just described, was present in the specimen next to be considered. This was from an adult human brain hardened, *in toto*, in Müller's fluid, with the membranes intact. The medulla oblongata was very carefully separated from its surroundings. A dorsal view of this, with the tela choroidea undisturbed, is represented in the stereograph which is reproduced in fig. 12, A and B (p. 239). In this figure there is evident a well-marked foramen of Magendie, whose lateral margins are ragged and everted. (The left margin has, however, been further pinned back for demonstration purposes.) These redundant and everted ragged margins represent a portion of the parietes of the dorsal-caudal ventricular evagination. The apparent posterior margin of the aperture is, however, smooth and crescentic, but its precise nature and relations cannot be fully apprehended from this figure alone. In fig. 13, A and B (p. 239), is reproduced a stereograph showing, at an initial magnification of four diameters, the details of the region under consideration. Here the distinction between the lateral boundaries, and the apparent posterior boundary, of the foramen of Magendie, is vividly shown. It is clear to demonstration, that the smooth crescentic fold, which here occupies the place of the obex, is an abrupt caudal reflection of the pia-ependymal roof overarching the region of the calamus; and that its dorsal surface must be understood to be covered by a layer of ependymal epithelium forming part of the lining of a dorsal-caudal prolongation

of the ventricular cavity. And it is plain that this membranous false obex (as it may be called) represents morphologically both the abortive obex itself and that pia-ependymal fold to whose presence Retzius has drawn attention.

Fig. 14, A and B (p. 239), represents a stereograph of the same specimen, after complete removal of the caudal part of the roof of the fourth ventricle. The line of attachment of the false obex may be seen as a fine white line, on each side, diverging from the region of the calamus scriptorius, and overhung by the very prominent clavæ, from whose surface the membranes have been in part removed. This figure should be compared with fig. 13, the point of view being practically the same in both.

The specimens above described sufficiently illustrate the two leading types of roof-structure in the region of the calamus scriptorius. They may be distinguished as those of true, and of false or membranous obex respectively; and to these two types the other slightly modified forms met with are easily reducible.

It is evident that the obex is essentially a development of the roof-plate of the neural canal; although it is ordinarily overlapped dorsally by the caudal-dorsal evagination of the cavity of the rhombencephalon or its remains.

§ V. Discussion of Morphogenesis of the Neural Canal.

Further examination of fig. 14 will show that the structural arrangements disclosed by the removal of the representative of the obex are by no means always perfectly simple in character. From the descriptions usually given one might be led to expect that, in such a dissection as that figured, there would be exposed simply the upper orifice of the rapidly expanding central canal of the lower part of the bulb. And in a certain number of instances this is actually the case. In these, the central canal, just before it becomes merged in the cavity of the rhombencephalon on issuing from under cover of the obex, is vertically elongated and cleft-like. It is a central canal of this simple character which is illustrated in the stereograph in fig. 7, and also in transverse section in figs. 9 and 10. But in the specimen now under notice (fig. 14) this is not the case. Two openings are here seen, one dorsal to the other, and both are overhung dorsally by the representative of the obex. Variations in the form, and modifications of the constitution of the neural canal of the bulb, below the plane of its confluence with the cavity of the rhombencephalon, are responsible for some of the vagueness and discrepancy of description already referred to. The form of the canal, and the constitution of its

parietes, are conditioned by the facts of development, ontogenetic and phylogenetic, and therefore a brief consideration of some of the factors involved in the morphogenesis of the canal will here be appropriate. Current conceptions of the fundamental morphological constitution of the neural canal are still based almost exclusively upon His's investigations into the development of the wall of the medullary tube. Through His's observations, anatomists learned to recognise a subdivision of the parietes of the neural canal into ventral or basal, and dorsal or alar laminæ, together with connecting roof- and floor-plates. Our knowledge of the morphological history and significance of these areas is still far from complete, and we may yet expect much additional light to be thrown upon these questions both by embryologists and comparative anatomists. The publication of such systematic studies as von Kupffer's "Morphogenie des Centralnervensystems" (1903–5) in Hertwig's comprehensive *Handbuch*, now appearing, promises to render available to anatomists generally, a rich store of facts and observations bearing upon the problem referred to.

As of special importance in this connection, I would call attention to the recognition by v. Kupffer, as a general characteristic of the fourth ventricle in those classes of lower vertebrates treated of in the chapters thus far published, of three longitudinal zones, bounded by furrows and distinguished by the writer as medial, lateral, and dorsal (*cf.* pp. 142–3, and figs. 166–7). It is obvious that these correspond with those elevations in man and the higher vertebrates, which form, at certain levels, the trigonum hypoglossi with the funiculus teres, the eminentia and ala cinera, and the trigonum acustici. In some of His's figures illustrative of the development of the rhombencephalon, we do, indeed, meet with the same plan of organisation. Figures like v. Kupffer's 124 or 166 correspond more or less completely to fig. 18, iv., from His (1888), or figs. 10–12 of the same author (1891).

His apparently did not recognise the differentiation of three longitudinal areas as of great morphological importance, and he leaves us to infer that the existence of a third longitudinal swelling of the medullary wall, in the region of the medulla oblongata, is conditioned merely by the development of the "Rautenlippe" or primary rhomboidal lip. That this is not the case is proved by v. Kupffer's statements and figures quoted above. But even in other figures from His (*e.g.* 24 and 27, 1888), where there could be no possible explanation by reference to the primary rhomboidal lip, it is plain that the author has passed over further manifestations of the triple organisation of the wall of the medullary tube, under the influence of his conception of its merely dual composition by dorsal and ventral zones.

It seems probable that this latter hypothesis was originally based upon the results of His's investigations into the development of the spinal cord (1886–87). There we have originally a simple sagittal cleft-like lumen; but very soon, at about four weeks (fig. 1), the lumen shows slight lateral extension to form a lateral sulcus on each side, which His speaks of as the "lateral furrow of the central canal" (*ib.* p. 498). At this stage he describes the lateral medullary wall as organised into two segments united by a short "Schaltstück." The two segments here referred to would appear to be his alar and basal laminæ (Flügel- and Grund-platte). But if this be so, the "Schaltstück" remains excluded from either lamina. It is, in point of fact, difficult to make out whether His did, or did not, intend to count the "Schaltstück" to one or other of the laminæ. Minot (1892, p. 662), in his summary of His's statements, defines the ventral zone (corresponding to His's "Grundplatte") as "consisting of an upper connecting-piece, His's Schaltstück, and a wider lower segment." Now His explicitly states that from the "Schaltstück" there takes origin the cervix cornu posterioris with Clarke's column (*ib.* p. 506), together with the chief mass of the processus reticularis, whilst its border-zone yields the myelospongium for the hinder part of the lateral white column. Minot has accepted this as meaning that "only part of the posterior horn of the adult is developed from the dorsal zone."

I greatly doubt that His actually credited the "Schaltstück" to *either* ventral or dorsal zones. But if he did, then I think that he can be shown to have excluded it from his "Grundplatte." Thus on p. 497 (*ib.*) he states that, "Im ganzen genommen gliedert sich das Rückenmark jederseits in zwei durch ein kurzes Schaltstück verbundene Abschnitte, die ich als vorderen Markcylinder und als hinteres Markprisma bezeichnen will." In his next paper, "Zur Geschichte des Gehirns" (1888, p. 351), he defines his four longitudinal zones and states that "Die Grundplatte wird zum Bezirke der Vorder- und Seiten-hörner und der zugehörigen Längsstränge (zu dem von mir so genannten vorderen Markcylinder). Die Flügelplatte liefert das Gebiet der Hinterhörner und theilweise das Gerüst der Hinterstränge." It is obvious that the above identification of the Grundplatte with the "Markcylinder," merely, of the previous paper, logically implies the exclusion from the latter of the "Schaltstück"; whilst the definition of the Flügelplatte ought strictly to include the "Schaltstück" as yielding a not inconsiderable portion of the posterior horns.

Nevertheless I am inclined to believe that, though Minot cannot be right in interpreting His as including the "Schaltstück" in the ventral zone or basal lamina, it would be likewise straining the description to regard it as included in the "dorsal zone." Possibly by defining it as a

tertium quid, His originally intended to allow it a certain independence. But if so the independence was not explicitly acknowledged, or, rather, was simply ignored in framing the now classical scheme of longitudinal zones. Evidence can, I believe, be brought in support of the view that this omission is not of merely formal and trivial consequence.

Soon after the appearance, in the human embryo, of the "lateral furrow of the central canal" illustrated in fig. 1, from His, there appears, during the fifth week, a second lateral furrow very definitely shown in fig. 2, from the same source. This second furrow is referred to in the text (1886–87, p. 506) as "der secundären oder vorderen Ausweitung des

FIG 1.—Reproduced from His (1886–87, fig. 6). Embryo "S1," N-L – 12·5 mm. About four and a half weeks.

FIG. 2.—Reproduced from His (1886–87, fig. 7). Embryo "Sch."

Centralkanales," thus implying his conviction that the posterior (or dorsal) of the two furrows now present, is the representative of the original "lateral furrow of the central canal." And, as the latter was held to limit the "Schaltstück" dorsally, at the medial wall, so now this secondary and anterior furrow is held to limit it ventrally, for, "in the angle behind it," is formed Clarke's column from the "mantle-layer" of the "Schaltstück."

We thus have, quite definitely limited by furrows at the lumen of the canal, as well as at the surface of the spinal cord, three longitudinal zones in each lateral medullary wall, between the roof- and floor-plates of the embryonic cord. Such an organisation of the medullary wall is shown with diagrammatic clearness in fig. 2, where the "Schaltstück,"

as defined by His, possesses to all appearance co-ordinate importance with the other two segments.

His has not explicitly stated his view regarding the derivation of the "secondary anterior" (ventro-lateral) furrow of fig. 2. From the relations of the more dorsal of the two furrows, however, to the "Schaltstück," and to the plane of the ventral margin of the oval bundle, it alone, as a single furrow, could possibly answer to the first-appearing "lateral furrow of the central canal" of fig. 1. It is, perhaps, more probable that the latter tolerably wide furrow is responsible for both of the lateral sulci found in the immediately succeeding stages. But in any case these two lateral sulci deserve definite recognition as dorso- and ventro-lateral sulci of the spinal medullary canal.

Minot also has specially remarked upon the definite curves of outline of the lumen of the central canal as deserving of closer study (1892, p. 659). So far as I am aware, they have not yet received adequate attention. I am convinced that one of the results of a closer study will be to lay emphasis upon the presence of *two* lateral furrows, with *three* longitudinal zonal subdivisions, in the lateral wall of the spinal neural canal.

In his recent *Laboratory Text-book*, Minot states, with regard to the structure of the medulla oblongata (1903, p. 211), that, "We distinguish here, as everywhere in the medullary wall, the dorsal and ventral zones.

"The lateral, or morphologically dorsal, limit of the ventral zone is marked by the exit of the lateral roots. The ventral limit of the dorsal zone is marked by the entrance of the sensory or ganglionic fibres." But v. Kupffer's figures and statements already referred to, regarding the organisation of the rhombencephalon in lower vertebrates, prove that in this region we have undoubtedly to deal, not with two zones, dorsal and ventral, but with three longitudinal areas. This view receives support, as we have seen, from certain of His's own figures.

These three zones may be designated, in accordance with v. Kupffer's nomenclature, as medial (or, perhaps better, ventral), lateral, and dorsal: the two sulci separating them may be named dorso-lateral and ventro-lateral, as above suggested in connection with the embryonic spinal cord.

It is beyond the purpose of the present paper to inquire how far representatives of these three zones may be represented in other regions of the brain. Appearances are not lacking, both in the mesencephalon and diencephalon of the embryo, which are suggestive of such an interpretation. Nor can the question of the possible association of the three zones with the nerve-root components be discussed; although, at any rate in the case of the rhombencephalon, such an association is probably an actual, and morphologically significant, fact.

The question of the fate of the three zones in the development of the spinal cord has, however, a special interest in connection with the anatomy of the transition-region between spinal cord and rhombencephalon in the adult. The later development of the central canal is referred to by Minot (1892, p. 659) as follows:—"About the eighth week the canal begins to contract between the dorsal zones until the walls first meet and then unite." This union takes place first dorsal to the dorso-lateral furrows. Figs. 1 to 5, reproduced from His's paper (1886-87), should be consulted in this connection. In fig. 4 (from His), the dorso-lateral furrows are still visible close to the obliterated portion of the lumen. This represents the condition observed

FIG. 3.—Reproduced from His (1886-87, fig. 8). Embryo "Zw," N-L = 18·5 mm. About seven and a half weeks.

FIG. 4.—Reproduced from His (1886-87, fig. 9). Embryo "Lo," N·L = 24 mm. About eight and a half weeks.

by His in an embryo of eight and a half weeks ("Lo."). In the succeeding fig. 5, representing a section of the spinal cord of a fœtus of about three months, obliteration of the lumen has proceeded so far as to overtake the dorso-lateral furrows, which are therefore involved in the obliterative process and are no longer visible. A similar condition is also illustrated by Minot's fig. 376 (1892), representing a section through the spinal cord of a fœtus of the tenth week. Here, however, although the dorso-lateral furrows have disappeared during the process of obliteration, the dorsal part of the canal is not only still quite traceable as a linear fusion, but the extreme dorsal part of the lumen is still patent. "In older stages all traces of the canal (both its cavity and its epithelium) have disappeared, not only between

the dorsal zones of His, but also between the upper part of the ventral zones" (Minot, *l.c.*). With this disappearance the possibility of distinguishing longitudinal zones in the cord is lost.

The causes and precise manner of obliteration of the dorsal moiety of the central canal in the embryo need not here be discussed at length. It will generally be admitted that these are in some way associated with the development and organisation of the dorsal white columns of the spinal cord. It becomes, therefore, a matter of extreme interest to recognise that, whereas the reduction or suppression of the dorsal portion of the central canal continues with tolerable uniformity, up to, and through, the lower part of the bulb, yet in that region of the latter where the dorsal white

FIG. 5.—Reproduced from His (1886–87, fig. 10).
From fœtus of about three months.

columns are approaching their termination (*i.e.* where they are generally spoken of as "diverging"), the central canal, being relieved of their disturbing and suppressing influence, tends to manifest, even in the adult, the embryonal type of organisation. A certain degree of actual divergence of the dorsal columns does, of course, occur; allowing of the development of a true dorso-median sulcus. As this sulcus is traced upwards it gradually widens and shallows, and at the bottom of it there becomes exposed, between the funiculi graciles, a median dorsal extension of the central grey matter, *i.e.* the dorso-ventrally thickened mass of the dorsal grey commissure. In the interior of this central grey matter, now superficially placed, the central canal—no longer hampered by the dorsal white columns—tends to exhibit its primitive embryonic form, ere it undergoes, at the calamus scriptorius, its ultimate transformation into the cavity of the rhombencephalon.

The precise form and characters presented by the central canal in the region immediately below the calamus are, however, by no means constant; a fact which will receive detailed illustration from the cases next to be recorded in this paper. The discrepancies in the extant descriptions of this transition-region are largely attributable to this inconstancy in structural character.

§ VI. Description of Case of Primitive and Uncomplicated Cleft-like Form of Bulbar Neural Canal in the Adult. (Specimen 2.)

I have recently studied a complete series of microscopical transverse sections through the calamus region of the adult human medulla oblongata which was cut after double-embedding in paraffin and celloidin.[1] Figs. 9 to 11, already referred to in a previous part of this paper, were taken from this series. The case is one of those in which I believe that the typical form of the canal of the medulla is preserved with unusual freedom from complications. It is in the light of the appearances here met with that I venture to suggest that all the other structural modifications of the canal occurring in this region are to be interpreted.

Fig. 15, from section 354 in the series from the calamus region of this specimen, illustrates the general structure of the bulb at the lower extremity of the inferior olivary nucleus. On one side the section just shaves the lower pole of the main olive; whilst on the opposite side the plane of section is slightly more cranially placed, so that the characteristic olivary arrangement is visible. The plane of this section closely corresponds to that of such figures as Henle's fig. 134, Kölliker's fig. 462, and Ziehen's fig. 174, all of which represent planes not very remote from that of our section. But of these only Ziehen's photomicrograph does justice to the precise arrangement

[1] The portion of the medulla sectioned was one of the blocks of a bulb which had been carefully hardened in alcohol for the purpose of Nissl staining. It was infiltrated with cedar-oil celloidin, passed through benzol into paraffin, and finally cut on a Minot microtome into sections 10 mikrons thick. The method employed is particularly well adapted to yield series of unmutilated sections of the most delicate material. It is, however, liable to one defect, inasmuch as it is difficult to get large sections free from numerous fine wrinkles due to the presence of the celloidin. These wrinkles do not flatten out under the ordinary warm-water treatment on the albumenised slides. I have subsequently succeeded in overcoming this difficulty, or of greatly minimising it, by carrying out part of the flattening-out process on the top of the paraffin-bath for a brief period in a chamber with an atmosphere of ether-vapour.

In the series under consideration the crinkled appearance frequently mars the elegance of the preparation as a whole; but, as the photographs testify, this involved little or no detriment to the region with which we are here specially concerned.

of the dorsal commissural grey matter at the bottom of the dorsal median fissure shown in our fig. 15 (p. 240). It is to be noted that the commissural grey matter projects into the dorsal fissure as a conical plug forming in section the apex of an inverted wedge. This apex meets, and is continuous with, the pial fold which occupies the fissure. The examination of other series of specimens proves that this arrangement is characteristic whenever the dorso-median fissure is developed as such. Chrome-hæmatoxylin sections reveal the fact that, whilst the wedge is mainly composed of neuroglia tissue, fine medullated fibres are visible in it as far as the projecting apex of the wedge. The lumen of the central canal, both here and for some distance below this level, is a fine dorso-ventrally elongated cleft 0·55 mm. in length. The distance of its dorsal wall from the surface of the grey commissural plug at the bottom of the dorso-median fissure is 1·5 mm. In section 344, *i.e.* 0·1 mm. higher up the brain-stem, the dorso-ventral extent of the cleft-like canal has increased to 0·82 mm., whilst its distance from the bottom of the fissure has slightly diminished to 1·35 mm. In section 327 the lumen has largely increased dorso-ventrally and is now 1·5 mm. in this dimension, whilst it has also substantially widened. Its distance from the bottom of the fissure has now diminished still further to 0·75 mm. From these various measurements it is evident that the increase of the canal is in a dorsal direction at the expense of, or, as one may express it, by the opening up of, the grey (mainly neuroglial) matter between the canal and the bottom of the dorso-median fissure. The sum of the measurements of the dorso-ventral diameter and of the distance of the canal from the surface, has been approximately constant. In the section 327 the plug of grey matter protruding into the bottom of the fissure has become extremely well-defined. A photomicrograph illustrating the structure of this region in the section at a magnification of 30 diameters is reproduced in fig. 16 (p. 240), in which, however, only the dorsal portion of the lumen of the canal appears. A further change is now noticeable in connection with the lining of the canal. This consists in the differentiation of a patch of specially elongated ependymal cells on either side of the newly opened-up dorsal segment of the canal; together with a slight irregularity and prominence of the opposing portions of the walls of the canal bearing this specialised epithelium. This latter feature would not attract attention in this section by itself, but it represents the first appearance of a prominence which assumes a greater and increasing importance as the sections are traced further in a cranial direction.

In section 284 (fig. 17, p. 240) the dorso-ventral extent of the central canal has further increased to 2·12 mm., and the distance of its dorsal extremity from the surface of the dorsal plug-like projection of grey matter, at the bottom

of the medium fissure, is now reduced to 0·24 mm. At this plane, moreover, the lumen has now taken on a definite contour. A distinct widening is present opposite the upper or dorsal portion of the ventral half of the lumen. Immediately above this the lateral walls bulge somewhat inwards, and these prominences are clothed by the strip of specially differentiated ependyma, already noted as present at a more caudal plane. Both dorsally and ventrally to this strip the ependyma thins out, but the ventral fourth of the lumen, representing the entire extent of the lumen lower down, is clothed by columnar ependyma cells. The dorsal fourth of the lumen, viz., the portion which has only at this level become patent, is still a very narrow cleft lined by an evident but shallow ependyma epithelium. It is noticeable that at its very dorsal extremity the lumen actually widens out to form an irregular dilated ependyma-lined space. Between this and the main lumen the walls are nearly in contact, but are nevertheless quite distinct.

A remarkably close resemblance is observable between the configuration of the canal here described and that figured by Minot (1892, fig. 376) in a section of the spinal cord of a human fœtus of 63–68 days. So far as the lumen is concerned, the resemblance is complete in every detail; and if comparison be further made with figs. 1–5, after His, there will be little hesitation in identifying the widening of the lumen in the specimen under consideration as due to the presence of a wide furrow on each side identical with the lateral sulcus of fig. 5, as well as that of Minot's fig. 376, and also with the more ventral of the two lateral sulci shown in figs. 2–4.

In section 260 (fig. 18, p. 240) the lumen has again slightly increased in dorso-ventral extent. It is now 2·31 mm., whilst its distance from the surface is now somewhere between 0·1 and 0·2 mm. The narrower dorsal moiety of the canal is still cleft-like, but its walls are no longer in contact. Besides the widening of the ventral segment of the lumen visible in the section last described, which is due to the partial persistence of the "ventro-lateral sulcus" of the embryonic canal, we have now a second lateral furrow, slighter, but more acutely marked, and lying just dorsally from the prominence which forms the dorsal boundary of the ventro-lateral furrow aforesaid. This second lateral furrow is obviously homologous with the "dorso-lateral sulcus" of the central canal of the embryonic spinal medulla. In the figure the dorso-lateral sulci of opposite sides do not lie exactly opposite one another, but this is owing to a slight obliquity of the plane of section. The specialised strip of ependyma referred to above, is now found to form the epithelial lining of the dorso-lateral sulcus.

In section 243 (fig. 10) the dorso-lateral sulci of the canal are well marked,

though still shallow, and dorsally to them the lumen has undergone some expansion, though it is still narrower than the ventral segment. The lumen as a whole is comparable with that of the embryonic spinal cord at the stage illustrated in fig. 3. At this plane the lumen measures 2·4 mm. dorso-ventrally, and its distance from the surface has undergone no further alteration.

Hitherto the apex of the wedge projecting from the central grey matter at the bottom of the dorsal median fissure has been narrow and sharp. But at the level now reached, the fissure has greatly shallowed and is widening out. The plug of grey matter is also broadening out to form a definite roof for the now gradually widening dorsal segment of the central canal. Still at this level, as posteriorly, the pia mater of the dorsal fissure is directly and intimately continuous with the subpial neuroglia tissue constituting the superficial portion of the roof in question. This thickened roof-plate, derived from the dorsal plug, has already, in a previous section of this paper, been identified with the caudal portion of a true obex.

In fig. 9, also previously described in connection with the question of the obex, there is represented the condition exhibited by section 236 of the series under consideration. Here the roof-plate, now a definite obex, is further expanded and thinned, and is continued dorso-laterally into wing-like expansions continuous with the pia mater. But between these wings its dorsal surface is now free from pial attachments, and forms a smooth depressed area which constitutes a small part of the floor of the backward continuation of the ventricular cavity, *i.e.* part of Blake's caudal protrusion. Part of the roof of the ventricle is visible at a higher level. Fig. 11, also referred to in the former section on the obex, illustrates the confluence of the cleft-like central canal with the fourth ventricle, in front of the anterior margin of the obex, as seen in section 218. Fig. 19 (p. 241), from section 210, gives a general view of the same region at a lower magnification.

The central grey matter is seen in the figure extending dorsally by the sides of the deep cleft which is now the deep median furrow of the ventricle. Traced in the dorsal direction, it gradually diminishes in thickness till the level of the surface of the dorsal white columns is reached, where it is prolonged on each side into the base of the tænia ventriculi. The lumen of what was, lower down, the central canal, and is now the median ventricular furrow, still resembles that shown in fig. 9. As there, so here, the dorso-lateral sulcus appears as a sharp notch. The ventro-lateral sulcus is only very slightly indicated, and the imperfection of the floor of the canal in this region tends to render

it still less evident. There is, nevertheless, little difficulty in recognising its situation on the right side of the section, midway between the dorso-lateral sulcus and the floor of the cleft. The whole of the ventral segment of the cleft, as far as the dorso-lateral sulcus, is lined by columnar ependyma. Dorsally from the same sulcus the ependyma consists of flattened cells. The dorso-lateral sulcus itself has, since its first appearance, been lined by more specialised ependyma cells. These are serially continuous below (*i.e.* caudally) with that narrow longitudinal strip of specialised ependyma whose presence was noticeable on the lateral wall of the central canal even before the appearance of the actual sulcus. At the plane now arrived at there is seen to be a special collection of neuroglia cells, underlying the ependyma cells of the sulcus, and forming a neuroglia septum extending outwards from the sulcus on each side into the surrounding grey matter.

Immediately dorsal to the dorso-lateral sulcus the lateral wall of the ventricular cleft exhibits a gentle prominence, extending as far as the base of the tænia ventriculi. This prominence is due to an increase in the mass of the ventricular grey matter lying dorsal to the neuroglia septum above described as running out from the bottom of the dorso-lateral sulcus. This area of grey matter has a peculiar and characteristic appearance. It represents the caudal continuation of the tissue of the area postrema of the rhombencephalon into the lateral wall of the cleft-like central canal. It was already visible, but was much less conspicuous, lower down—in fact as far in a caudal direction as one can recognise the dorso-lateral sulcus itself (*cf.* figs. 10 and 17). Now, however, it forms a distinctly evident area in the cross-section, attracting attention by peculiarities of texture. These are in part due to its special vascularity. In section, it appears dotted throughout by the cross-sections of numerous blood vessels of small size, many of which are small arterioles with relatively thick muscular walls. Independently of this marked vascularity, however, the supporting myelospongium is of remarkably loose and open texture; much more so than that of the grey matter elsewhere around the canal, or ventricle. This delicate and loose myelospongium is continued dorsally, though with gradual modification in character, into the base of the ligula.

As the series of transverse sections is traced further in a cranial direction, the cleft-like median ventricular furrow gradually opens out and shallows. The process of opening-out naturally first affects the dorsal segment of the canal, so that the area postrema gradually comes to lie exposed upon the floor of the ventricle. This condition is shown as partially attained in fig. 20 (p. 241), illustrating section 156 of the present series. Here the area postrema is seen extending upon the floor of the ventricle, especially upon the left side.

Here the slight obliquity of the section more nearly coincides with the oblique direction of the area postrema; whilst on the opposite side the latter is cut more transversely to its long axis. For the same reason the dorso-lateral sulcus appears more shallow on the left than on the right. The ventral segment of the ventricular furrow is imperfectly preserved, yet on the left side it is easy to recognise the position of the ventro-lateral sulcus. The slightly prominent area of the lateral wall of the ventricular furrow, between the dorso- and ventro-lateral sulci, is the caudal continuation of the base of the ala cinerea.

The systematic examination of the series of transverse sections under consideration has thus shown that, as we ascend from the lower region of the bulb to the fourth ventricle, we witness an emancipation of the central canal from the conditions which have determined its dorso-ventral reduction lower down, and a return to something approaching the embryonic contour of its lumen. We are able to distinguish dorso-lateral and ventro-lateral sulci, which delimit three longitudinal zones, viz. (*a*) a dorsal zone represented by the area postrema and its caudal continuation into the lateral wall of the cleft-like central canal; (*b*) a lateral zone represented by the area intermediate between dorso- and ventro-lateral sulci, and continuous in a cranial direction with the ala cinerea; and (*c*) a ventral zone corresponding to the hypoglossal funiculus or funiculus teres and its caudal prolongation into the central canal.

I submit that a comparison with the embryonic characters of the medullary canal leaves little room for doubt that the whole of the lateral wall of the ventricular cleft dorsal to the dorso-lateral sulcus, and extending as far as the obex and tænia (*cf. e.g.* figs. 9, 10, 18, and 19), corresponds with the dorsal zone or alar lamina of His. The sole derivative, therefore, of that longitudinal zone of the medullary parietes, in this calamus segment of the bulb, is the area postrema. The ala cinerea and its caudal continuation form an intermediate or "lateral" zone of the medullary parietes lying between the dorso- and ventro-lateral sulci. It is morphologically distinct from the genuine "dorsal zone" of His, and probably corresponds to the "Schaltstück." The ventral zone of His lies wholly ventral of the ventro-lateral sulcus. The subdivisions specified are indicated with almost diagrammatic clearness in fig. 21 (p. 241) from a human fœtus of the sixth month. Here the primary nature of the dorso-lateral sulcus is hardly open to doubt; and, if that be admitted, the homology of the area postrema to the entire dorsal or alar lamina of His almost inevitably follows (*cf.* especially fig. 3, after His).

EXPLANATION OF FIGURES (Figs. 6–21).

(*N.B.*—The stereoscopic figures Nos. 7, 12–14 should be viewed with the aid of a stereoscope.)

Fig. 6 (magnification × 7 diameters).—Transverse section of medulla oblongata of human adult, to show the character of the ventricular roof at a plane which is, if anything, further in a caudal direction than Ziehen's fig. 176, purporting to pass through the obex. (Celloidin-embedding: Pal staining.)

Fig. 7 (× 6·2).—Stereophotomicrograph showing "typical" form of calamus region of adult human bulb (specimen vii.). A "true obex," triangular in form, is seen roofing over the cleft-like lumen of the neural canal at its vestibular opening into the cavity of the fourth ventricle. The three longitudinal zones of the lateral wall of the rhombencephalon ("floor of the fourth ventricle") may be seen converging caudally to enter into the composition of the lateral walls of the cleft-like central canal of the bulb. The dorsal aspect of the obex is clad with ependymal epithelium, which is reflected, at its caudal and lateral limits, into the pia-ependymal parietes of the caudal-dorsal protrusion of the ventricular cavity.

Fig. 8 (× 29).—Small portion of a transverse section passing through the apical (*i.e.* caudal) part of the triangular obex of the specimen shown in fig. 7. Only the dorsal portion of the narrow lumen of the central canal is visible in the figure. The thick but narrow roof-plate bridging over the cleft is the obex. Its dorsal surface is clad by ependymal epithelium: this is part of the lining of a dorsal space with largely membranous parietes. This space is continuous with the ventricular cavity in front, and is representative of the original caudal-dorsal evagination of the cavity of the rhombencephalon.

Fig. (9 × 23).—Part of transverse section through adult human bulb (specimen ii.). The section reveals the "typical" form of the central canal, immediately posterior to the plane of its expansion into the cavity of the fourth ventricle. A "true obex" is seen, as in fig. 8. Dorsal to this is the backward prolongation of the ventricular cavity. In the lateral wall of the cleft-like central canal the "dorso-lateral sulcus" is present in well-marked form on the right side. Dorsal to it the lateral wall is bulged inwards in a gentle prominence, formed by the caudal continuation of the area postrema with its "nucleus postremus."

The "ventro-lateral sulcus" is only slightly indicated opposite the widest part of the ventral half of the canal.

Fig. 10 (× 29).—Another section (specimen ii.) through a plane a little behind that of fig. 9. It passes through the thicker caudal part of the obex. The section practically coincides with the line of pia-ependymal reflection from the dorsal surface of the obex. This reflection is described by Retzius, and is regarded by him as representing the true morphologically caudal boundary of the foramen of Magendie.

The dorso-lateral sulcus of the central canal is here readily distinguishable on both sides. Immediately ventral to it is seen a prominence due to the presence of a specialised strip of ependyma, representing the caudal continuation of the "funiculus separans" of Retzius.

Fig. 11 ($\times$ 42).—Part of section through calamus region of same specimen. The plane lies immediately in front of the anterior free border of the obex. The cleft-like central canal is now confluent dorsally with the expanded part of the ventricular cavity. It is therefore now a "median furrow of the floor of the ventricle." A relic of the lateral part of the obex is visible on the right side. On the left, its thick ligular continuation ("tænia ventriculi") is seen tapering into the expanded pia-ependymal roof.

Fig. 12 ($\times$ 1·6).—Dorsal aspect of adult human bulb (specimen vi.). The ventricular roof is intact, and a "foramen of Magendie" is seen. The margins of the latter are prolonged into the parietes of the extra-ventricular space which in part represents the original "caudal protrusion" of the ventricular cavity. These margins have been further everted and pinned backwards. The apparent caudal boundary of the foramen of Magendie is formed by a smooth crescentic "membranous" or "false" obex. The caudal reflection of the pia-ependymal roof takes place along the line of the root, or posterior attached margin, of this "false obex."

Fig. 13 ($\times$ 4).—Foramen of Magendie of same specimen, seen under slightly increased magnification. The details of arrangement of the margins of the foramen are clearly demonstrated in this stereograph, and the membranous character of the "false obex" is apparent. Through the open foramen the vestibule of the central canal of the bulb is visible. This is crossed by the "intercinereal commissure subdividing ventral and dorsal portions of the (primitively cleft-like) canal. The dorsal subdivision constitutes a "supra-commissural recess."

Fig. 14 ($\times$ 4).—The same specimen shown in figs. 12 and 13. The ventricular roof has been removed from the calamus region, so that the vestibule of the central canal is more completely shown. The "intercinereal commissure" is plainly formed by a median fusion of funicular prolongations of the alæ cinereæ. The so-called "funiculus separans" is visible, especially upon the right side (of the figure), as a white stria skirting the dorsal border of the cinereal funiculus of the ventricular floor. Traced caudally, it becomes indistinct along the ventral lip of the dorso-lateral sulcus. The postremal columns are very prominent. The ragged linear site of attachment of the ventricular roof is very obvious.

Fig. 15 ($\times$ 8).—Portion of transverse section below the calamus region of the same specimen from which figs. 9–11 are reproduced (specimen ii.).

The apex of the dorsal commissural wedge is seen projecting at the bottom of the dorsal median fissure. The central canal at this plane shows only a very small slit-like lumen representing merely the most ventral portion of the cleft visible in figs. 9–10. Its obliterated dorsal portion is even here represented by a track of paler tissue which extends from it in a dorsal direction. In the more dorsal region of this track there may be discerned, under higher magnification, the remains of ependymal epithelium.

Fig. 16 (×30).—Part of a section of specimen ii. about 0·3 mm. above the plane of fig. 15. Here the cleft-like canal has substantially increased through its further dorsal extension into the mass of the dorsal grey commissure. The latter still projects into the dorsal median fissure. In the extreme dorsal region of the lumen of the canal there is seen on either side a patch of specially thickened ependyma.

Fig. 17 (×29).—The section cuts a plane about 0·43 mm. higher up than fig. 16. Here the canal has attained further dorso-ventral extension. The patch of thickened ependyma which had become evident in the previous figure is now more distinctly localised, constituting the thickened ependymal strip noted in fig. 10. Immediately dorsal to it the dorso-lateral sulcus is about to become indicated, as in figs. 9 and 10. But the virtual lumen already extends much further in a dorsal direction. A small dilatation of its extreme dorsal portion is now discernible in the base of the wedge-shaped plug which forms still a papillary projection at the bottom of the dorsal median fissure. By this extension of the lumen into the base of the plug the latter becomes an evident roof-plate, and is as such directly continued into the caudal part of the obex.

Fig. 18 (×18).—The plane of this section lies 0·25 mm. higher up than that of fig. 17. The dorso-ventral extent of the lumen has now reached its maximum. The plane may be regarded as that of the caudal limit of the obex. It lies about 0·17 mm. behind the section figured in fig. 10. (The differences in magnification must be taken note of.) This is the lowest plane illustrated in which the peculiar differentiation of the tissue forming the walls of the cleft-like canal, dorsal of the dorso-lateral sulcus, can be recognised. This tissue forms the hindmost portion of the "nucleus postremus."

Fig. 19 (×23).—The section passes very slightly above the plane illustrated in fig. 11 from the same specimen. The floor of the ventricular furrow is imperfect, but the dorso-lateral regions show typical structural arrangements. The dorso-lateral sulcus is very definite, and the thickened strip of ependyma (funiculus separans) bordering it ventrally, and extending into it, is quite apparent in the photograph, especially with the aid of a lens. The nucleus postremus, dorsal to the sulcus, has increased in bulk and definiteness.

Fig. 20 (×18).—This section is from a plane a little over half a millimetre in front of that illustrated in fig. 19. The dorsal portion of the ventricular cleft is now rapidly opening out. The lateral walls ventral of the dorso-lateral sulcus are unfortunately damaged. The cushion-like area postrema forms a marked projection on each side. The section is slightly oblique, so that the area is cut more or less transverse to its long axis on the right, and more obliquely on the left of the figure. The neurones of the "nucleus postremus" are seen to be very numerous, and form a very well-defined group. The neuronic groups belonging to the vagus and hypoglossal nerves are clearly evident on the right side. The section was stained with methylene blue.

Fig. 21 (×23).—From a transverse section of a human fœtal bulb showing typical cleft-like neural canal. In its walls are situated the sharply indented dorso-

lateral, and the wider and more indefinite ventro-lateral sulci. Between these furrows is the cinereal funiculus or intermediate zone of the medullary wall. The exceedingly prominent areæ postremæ of opposite sides are in contact slightly, but are not fused medially. The cleft-like canal extends dorsally between them, and suddenly widens out dorsally in the horizontal direction. The thin and expanded pia-ependymal roof is lacking, but a trace of its lateral attachment may be detected, especially on the right, at the dorso-lateral angle of the postremal mass.

The ependymal epithelium lining the canal below the level of the dorso-lateral sulcus is of high columnar character. That lining the ventricular space above that level and covering the surface of the postremal area is flattened and inconspicuous. The epithelium lining the bottom of the dorso-lateral sulcus is specially elongated.

(Part II. of this paper will appear in the July number of the Journal.)

Fig. 6.

A B

Fig. 7.

Fig. 8.

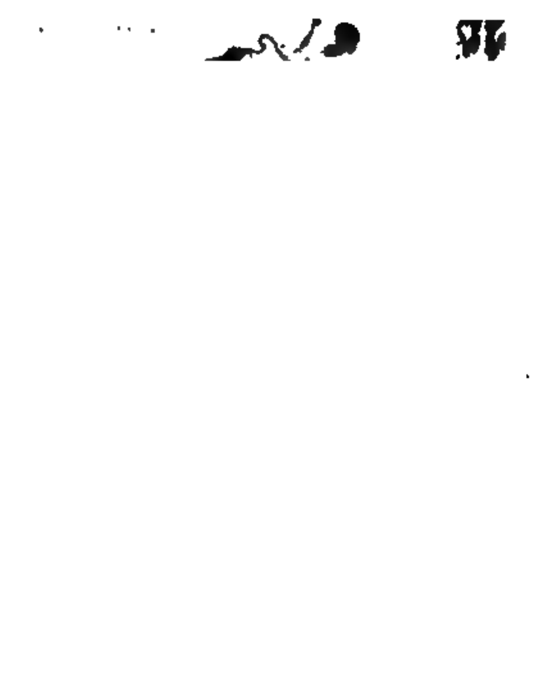


Fig. 9.

Fig. 10.

Fig. 11.

A B

Fig. 12.

A B

Fig. 13.

A B

Fig. 14.

Fig. 15.

Fig. 17.

Fig. 16.

Fig. 18.

Fig. 19.

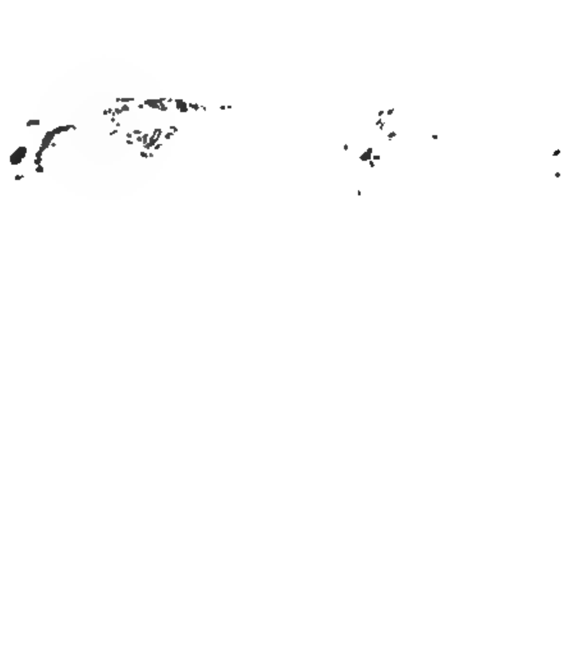


Fig. 20.

Fig. 21.

NOTES ON THE CORONAL SUTURE.[1] By F. G. PARSONS,

St Thomas's Hospital Medical School, London, S.E.

ON looking at a human parietal bone, it is well known that its anterior border undergoes a change below the place where the temporal ridge crosses it. Above this point it is serrated, below it overlaps the frontal in a more or less squamous manner.

In some skulls there is a slight though definite angle at the stephanion, the point of crossing of the temporal ridge.

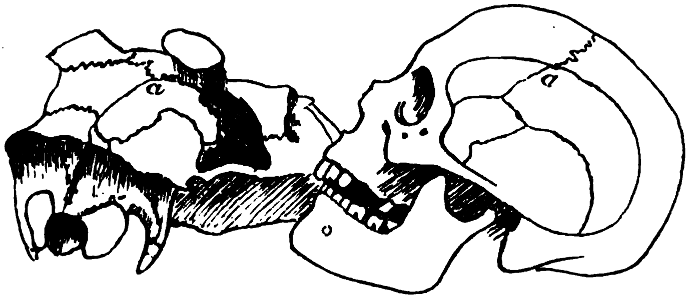


FIG. 1.—Skulls of man and red deer. *a*. Pterion.

In looking at the coronal suture of a ruminant such as a sheep or deer, one is struck by the much greater accentuation of this angle and by the way in which the outer table of the parietal overlaps the frontal for an enormous distance in a downward and forward direction. It long ago occurred to me that this was caused by the forward pull of the temporal muscle in retracting the jaw, that as it pulled the jaw back it gradually pulled the outer table of the parietal forward; but there were many difficulties connected with mammalian skulls which I could not account for then, but which, I think, I now can. In the first place, the coronal suture of the Carnivora is quite straight and shows no angle; this I account for by the fact that in the Carnivora the lower jaw joint is a perfect hinge and allows no forward movement, consequently the temporal is never used as a retractor, and would not be expected to pull forward the parietal. In the herbivorous marsupials, like the kangaroo and wallaby,

[1] Read before the Anatomical Society of Great Britain and Ireland, November 24, 1905.

the bending of the suture is nearly as great as in the ruminants, but in the carnivorous ones it is not so. The rodents were my greatest difficulty, because in them the lower jaw hardly opens at all in our sense of the word,—it slides backward and forward in an antero-posterior groove, and here, if anywhere, the effects of the temporal on the coronal suture should be evident. So it is in the squirrel-like rodents, the squirrel, the beaver, and the marmot; but in those of the porcupine-like suborder, although the lower jaw moves forward and backward just as freely as in the others, the coronal suture is quite straight, and there is no pulling forward of the lower end of the parietal bone at all. This is the case in the viscacha, the capybara, the agouti, and the coypu, and I now see that the reason for it is that the temporal muscle is so small and low that it does not pass over the

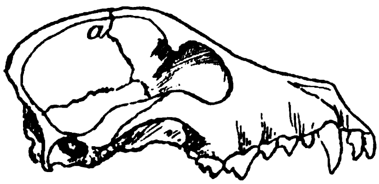


FIG. 2.—Skull of dog. *a.* Pterion.

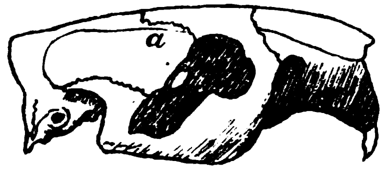


FIG. 3.—Skull of beaver. *a.* Pterion.

coronal suture at all, but over the squamosal bone, so that these animals have no stephanion on their skulls, and of course the coronal suture is unaffected. In the porcupine itself the muscle does just cross the lower edge of the coronal suture, and in it there is a slight though marked angle at the point of crossing.

That the temporal muscle is responsible for the simple form of the coronal suture below the stephanion in man, the evidence of comparative anatomy goes to show; but why the suture should commence to be obliterated there, is part of a larger inquiry, and I am now seeking an explanation.

While talking about the coronal suture, I should like to show two photographs of a skull, from the great collection at Hythe, in which one side of the coronal suture has been prematurely obliterated with the usual lateral distortion due to stoppage of growth in length on that side, but the point which struck me as interesting is that the growth in height is also stopped on that side.

A NOTE ON THE TOPOGRAPHICAL ANATOMY OF THE CAPUT GYRI HIPPOCAMPI.[1] By JOHNSON SYMINGTON, M.D., F.R.S., *Professor of Anatomy, Queen's College, Belfast.*

THIS part of the gyrus hippocampi is of considerable morphological and physiological importance, since it corresponds to the pyriform lobe of mammals and is the main cortical centre for smell. Its boundaries and certain markings on its surface have been investigated with great care by

FIG. 1.

Professor G. Retzius,[2] but its relations to the cranial wall appear to have been overlooked, although these are not without interest in connection with its general form and surface markings. Retzius has described a fissure on its surface which he terms the *sulcus rhinencephalus inferior*. This fissure is directed from before backwards, and is generally situated a little below and in front of the anterior end of the hippocampal sulcus, where

[1] Read before the Anatomical Society of Great Britain and Ireland, November 24, 1905.
[2] *Das Menschenhirn*, 1896.

this forms the lower boundary of the *uncus*. Occasionally it is in line with this sulcus. Retzius admits that the inferior rhinencephalic sulcus varies considerably in depth, being sometimes very shallow and in other cases appearing as a well-defined fissure. He was able to recognise its existence in sixty-nine out of one hundred hemispheres.[1]

During the examination of a series of adult human brains hardened *in situ* by the injection of formol, I invariably found a groove in the position of the fissure described by Retzius, and by making dissections of the brain *in situ*, I found that this groove was occupied by the anterior part of the

Fig. 2.

free edge of the tentorium cerebelli, a little behind the anterior clinoid process and external to the third nerve. These relations are most readily shown by making a median section of the head and then dividing on each side the upper part of the crus cerebri and removing the portion of the brain below this cut (figs. 1 and 2). By this means the relation of the free edge of the tentorium cerebelli to the brain is easily ascertained. On such preparations it will be seen that this edge passes forwards and downwards from just behind the splenium of the corpus callosum across the isthmus, uniting the callosal and hippocampal gyri, and occasionally indenting it. It then passes into the depression between the upper border of the lateral aspect of

[1] *Das Menschenhirn*, Text, S. 74.

the pons Varolii and the crus cerebri. In front of this it again comes into close relation with the cerebral cortex, and on the caput gyri hippocampi corresponds to a distinct longitudinal depression. The lower part of the caput lies against the dura mater in the middle fossa of the base of the skull, where the dura mater forms the outer wall of the cavernous sinus. The upper part bulges upwards and inwards above the edge of the tentorium and presents an uneven surface, being marked by the gyrus lunaris and gyrus ambiens of Retzius and continued backwards to form the uncus.

The question arises as to whether this tentorial impression should be described as a sulcus. In the great majority of cases it merely represents a change in direction of the cortical surface of about 90°, and it is only occasionally that the bottom of the groove is prolonged into a shallow fissure with the two walls parallel with one another. The superficial character of the impression is shown in nearly all the illustrations given by Retzius (see Tafeln lxi., figs. 3 and 4; lxiii., fig. 2; lxv., figs. 1 and 2; lxvi., fig. 2; lxix., fig. 3; lxxii., figs. 2 and 3; lxxiii. figs. 3 and 4; lxxiv., figs. 3 and 4; lxxxii., fig. 2, and xc., fig. 10). In Tafeln lxi., fig. 2, and lxix., fig. 4, it is deeper than usual, and in the description of the former figure Retzius writes, "Der Sulcus rhinencepali inferior ist ausserordentlich stark entwickelt."

In my own specimens I have always found the groove present in brains hardened *in situ*, but have never observed it to possess the appearance of a clean-cut fissure.

It appears to me to be of the same nature as the transverse depression bounding the so-called post-orbital limbus,[1] which is sometimes found on the orbital surface of the frontal lobe opposite the free border of the lesser wing of the sphenoid, to Schwalbe's notch on the lateral border of the hemisphere, and to the depression on the inner side of the occipital pole of one of the hemispheres due to a lateral deviation of the posterior end of the superior longitudinal sinus, and I do not think it ought to be regarded as an ordinary cerebral sulcus.

Occasionally the inferior part of the caput is marked by a short sulcus which occurs along with the tentorial impression, but takes an oblique or a coronal direction. An illustration of this fissure is shown in Tafel lxxxii., fig. 3, of Retzius's *Menschenhirn*.

[1] E. A. Spitzkat, "The Post-orbital Limbus, a Formation occasionally met with at the base of the Human Brain," *The Philadelphia Medical Journal*, April 1903.

THE VERMIFORM APPENDIX OF MAN, AND THE STRUCTURAL CHANGES THEREIN COINCIDENT WITH AGE.

By RICHARD J. A. BERRY, M.D., F.R.C.S. Edin., F.R.S. Edin., *Professor of Anatomy, University of Melbourne*; and L. A. H LACK, M.B., Ch.B. Edin., *Indian Medical Service.*[1] *(From the Research Laboratory of the Royal College of Physicians of Edinburgh.)*

IN a paper on "The True Cæcal Apex, or the Vermiform Appendix: its Minute and Comparative Anatomy," published by Dr R. J. A. Berry in the *Journal of Anatomy and Physiology*, New Series, vol. xv. page 83, it was shown that lymphoid tissue is the characteristic feature of the cæcal apex and that the vermiform appendix of man is represented in the vertebrate kingdom by a mass of lymphoid tissue, situated most frequently at the cæcal apex. As the vertebrate scale is ascended, this lymphoid tissue tends to be collected together into a specially differentiated portion of the intestinal canal—the vermiform appendix—which is not therefore a vestigial structure, but is on the contrary a specialised part of the alimentary canal.

The paper, the conclusions from which have just been quoted, dealt exclusively with the lower animals from Pisces to Anthropoids. The present work, on the other hand, deals only with the vermiform appendix of man, and is therefore the necessary corollary and continuation of the former communication.

In the interval which has elapsed between the appearance of Berry's first paper, previously quoted, and the completion of the present work, our knowledge of the minute structure of the human appendix has been considerably advanced by the publication, amongst other papers, of C. B. Lockwood's *Appendicitis: its Pathology and Surgery*, and consequently one of the primary objects originally laid down some ten or more years ago, when the outlines of a research upon the vermiform appendix were being devised, has been allowed to fall into a secondary position, making way for the consideration of the very much more important questions:—

1. At what age does lymphoid tissue first appear in the human appendix?
2. At what age, if at all, does that lymphoid tissue tend to disappear?

[1] Read at the First International Federative Congress of Anatomy—Geneva, August 1905.

3. Is obliteration of the human appendix a physiological process, as affirmed by Ribbert, or a pathological condition as asserted by others?

The present paper is an attempt to furnish satisfactory and convincing answers to these important queries, and incidentally and secondarily to demonstrate what is to be regarded as the normal structure of the vermiform appendix of man. With these objects in view, the authors have cut 103 human appendices of both sexes and of all ages, from the full-term fœtus up to eighty years. The majority of the preparations were stained in hæmatoxylin and eosin.

1. *At what age does lymphoid tissue first appear in the human appendix?*—In Berry's first paper dealing with the lower animals he showed that at birth there is but little lymphoid tissue in the rabbit's appendix, but that within a week after birth the lymphoid tissue has increased to such an extent as to convert the rabbit's appendix into a lymph gland.

In the full-term fœtal kitten it was again shown that the cæcal apex contains practically no lymphoid tissue, but that at seven days old the lymphoid tissue is the most prominent feature of the cæcum and is already collected into germ centres, though, perhaps, not to such an extent as in the older animals.

As with the rabbit and the cat, so also with the pigeon. At birth there is practically no lymphoid tissue within the cæcum, but seven days later the two short cæca are characterised by a marked preponderance of that tissue.

Man differs but little, if at all, from the lower animals in this respect. In the vermiform appendix of the full-term human fœtus there is practically no lymphoid tissue, or at least so little as to constitute a negligible quantity, whilst lymph follicles are absent (see fig. 1).

Within fourteen days at least two well-marked lymph follicles have made their appearance, and lymphoid tissue is scattered profusely throughout the whole of the mucosa (see fig. 2).

At six weeks the increase is somewhat startling. There are eight to twelve lymph follicles, and the whole of the mucosa and sub-mucosa are densely infiltrated with lymphoid tissue (see fig. 3).

At thirty-two weeks the vermiform appendix of man is to all appearances an actively functional gland (see fig. 4). There are, in the plane of a transverse section, about ten to twelve well-marked and large lymph follicles and about 160 tubular glands, which last are actively functional, as proved by the mucous and other cells in the lumen of the appendix.

The answer to the question "At what age does lymphoid tissue first appear in the human appendix?" is then sufficiently obvious. In all the lower animals examined by Berry the amount of time required

for the evolution of lymphoid tissue in the appendix or cæcal apex was at most one week. In man, as shown by the present research, it is somewhat longer, namely, a month to six weeks, though it is quite probable that a prolonged investigation of human infants from one day to three weeks might reduce this time; but so far as our present knowledge goes it is sufficiently clear that there is no lymphoid tissue in the cæcal apex of the lower animals nor in the appendix of man at the time of birth, but that within one to six weeks the portion of gut under consideration has become an actively functional lymph gland.

Before passing to the consideration of the second question enunciated in the commencement of this paper, it will be advisable to say something of the normal structure of the human appendix. This question has been so thoroughly worked out by C. B. Lockwood of London that it is unnecessary to do more than briefly refer to it.

In the human appendix there is an external serosa or peritoneal coat (see fig. 5). This coat is continuous with the peritoneum of the meso-appendix; and here, in view of the numerous discrepant statements made by surgical writers, it may be as well to say that whether the meso-appendix does or does not appear to extend to the apex of the appendix the fact remains that the appendix is always entirely surrounded by peritoneum, except in those rare cases where it occupies a retro-cæcal or retro-colic position, in which event the serosa may disappear by fusion in much the same way as happens to the descending meso-colon of the fœtus, as pointed out by Symington.

Internal to the serosa is the external longitudinal muscular coat, the thickness of which differs considerably at different ages, and in which there is, according to Lockwood, a hiatus muscularis for the transmission of vessels. The present authors have not succeeded in finding this hiatus with anything like the constancy described by Lockwood.

The circular muscular coat, internal to the longitudinal muscular coat, again differs considerably in thickness at different ages.

Immediately internal to the muscular coverings comes the submucosa composed of connective tissue, blood-vessels, nerves, and lymphatics. It varies in thickness more than any other coat of the appendix, and is very frequently invaded by the lymph follicles and tissue from the mucosa.

The thin muscularis mucosæ separates the submucosa from the mucosa, but differs very widely in its development in different individuals.[1]

[1] Birmingham, who has published two excellent figures of the structure of the vermiform appendix in a child of two years and in an adult aged fifty-six, holds that the muscularis mucosæ is placed internal to the lymphoid follicles. (*Text-book of Anatomy*, edited by Cunningham).– Ed.

Fig. 1.—Full Term Fœtus. Male.
To illustrate the absence of lymphoid follicles in the vermiform appendix at birth.

Fig. 2.—Female. Aged 14 days.
To illustrate the appearance of the lymphoid follicles.

Fig. 3.—Male. Aged 6 weeks.
The conversion of the human appendix into a lymph gland.

Fig. 4. Aged 32 weeks.
The vermiform appendix as an actively functional lymph gland.

Fig. 5.—Female. Aged 10 weeks.
To illustrate the normal structure of the human appendix.

FIG. 6.—Male. Aged 19 years.
To illustrate the amount of lymphoid tissue as contrasted with fig. 7.

FIG. 7.—Female. Aged 80 years.
To illustrate the absence of lymphoid tissue as contrasted with fig. 6.

FIG. 8.—Female. Aged 24 years.
To illustrate the functional activity of the vermiform appendix during the first half of life.

FIG. 9.—Male. Aged 45 years.
To illustrate the onset of decadence with advancing age.

FIG. 10.—Female. Aged 58 years.
Pathological obliteration of the vermiform appendix.

FIG. 11.—Female. Aged 17 years.
To illustrate the presence of the whipworm (*Trichocephalus Hominis*) in the human appendix.

The most internal coat is the mucosa itself, chiefly composed of tubular glands embedded in lymphoid tissue, and of lymph follicles together with a vascular and lymphatic system and nerve endings. Internal to all, and separating the mucosa from the lumen, is a single layer of columnar epithelial cells resting upon a delicate basement membrane. This last is very easily destroyed, thus greatly facilitating the entrance of bacteria from the lumen of the gut into the mucosa of the appendix.

The number of tubular glands present in the mucosa varies very considerably, and undoubtedly diminishes with advancing age; thus we find between the ages of 11 and 20 years an average of from sixty to seventy tubular glands, whilst between the ages of 70 and 80 the average number dwindles to about thirty, and even these are very much atrophied.

The lymphoid follicles constitute the most striking feature of the human appendix. Each follicle consists of two parts—a central part which stains more lightly than the rest, and a cortical part which stains deeply. Each follicle is either surrounded by a basilar lymph sinus or merges imperceptibly into the lymphoid tissue of the mucosa or of a neighbouring follicle. The number of the follicles varies, as will be shown later, with age.

Passing now to the consideration of the second problem, "*At what age, if at all, does the lymphoid tissue tend to disappear from the human appendix?*" it may be at once admitted that it is not easy to furnish a satisfactory answer.

Changes in mucous membranes are apparently so easily induced by vascular conditions, by pathological processes of all natures, by dietetic variations, and by numerous other morbid and physiological changes, that there are obviously many pitfalls in endeavouring to answer such a question as the one now propounded. It must, however, be borne in mind that what is now proposed is an investigation of the time at which lymphoid tissue tends to disappear from the human appendix; that every appendix which displayed any tendency to obvious morbid change was cast on one side as useless for the present research, and that those which remain have all been submitted to a skilled pathologist with a view of eliminating any appendix obviously pathological in character. But even with these precautions it is not easy to furnish a satisfactory answer.

That the lymphoid tissue does tend to disappear from the human appendix is certain. The fact may be proved in two ways.

First, if the number of lymph follicles visible in a transverse section of any appendix be counted they will be found to become less numerous with advancing age; and, secondly, a comparison of an appendix from the first decade of life with one from the last decade of an aged person will be even more conclusive.

As regards the first line of proof, we divided all the appendices examined into decades, counting the number of lymph follicles in each section. On striking an average the following results, sufficiently conclusive in themselves, are obtained:—

The average number of lymphoid follicles present in a single transverse section through the centre of the human appendix are:

Below 1 year	5
Between the ages of 1 year and 10 years	6
„ „ 10 and 20 years	7
„ „ 20 „ 30 „	6
„ „ 30 „ 40 „	3
„ „ 40 „ 50 „	3
„ „ 50 „ 60 „	2
„ „ 60 „ 70 „	Traces only.
„ „ 70 „ 80 „	Practically none.

The total number of lymphoid follicles in any one appendix is, between the ages of 10 and 20, something like 200, which progressively diminish in the above-mentioned ratio.

The second line of proof—an examination of appendices at the extremes of life—affords even more striking evidence of the fact that lymphoid tissue tends to disappear from the human appendix. If, for example, the appendix of a person age 19 years (see fig. 6) be contrasted with that of a person age 80 (see fig. 7), it will be found that in the former the lymphoid follicles are more numerous and are larger than in the latter—numbering about seven to nine in the first case, with not more than the feeblest traces of two in the second case. The lymphoid tissue itself is also much more sparse in the elderly person than in the young person, and in many elderly persons is almost completely absent.

It must be remembered that we do not state that lymphoid tissue actually and totally disappears from the appendix, but merely that it tends to disappear, and that this tendency commences, in the majority of persons, about middle life. This therefore is our answer to the question propounded:—Lymphoid tissue never totally disappears from the appendix, but is present in much greater amounts in early life, diminishing about middle life, and from that onwards shows a progressive tendency to disappearance, without ever reaching total extinction.

Having answered the question, and having adduced two lines of proof in support of that answer, it may now be advisable to follow out the gradual changes in the mucosa of the appendix.

It has already been shown that lymphoid tissue makes its appearance

within the appendix in from four to six weeks after birth, at which period the appendix is to all practical purposes an actively functional lymph gland. If the examination be strictly limited to perfectly healthy appendices there are no very obvious changes until after 30 years of age (see figs. 8 and 9); at that period the lymph follicles tend to become flattened, diffuse, and aggregated, whilst the mucosa commences to show signs of atrophy. To this general statement there are, of course, individual exceptions; but the broad fact remains that until the fourth decade the vermiform appendix is an actively functional lymph gland, but that during that decade its function, as evinced by its structure, is much less active. During the fifth decade the lymphoid follicles have not only actually diminished in number but have assumed a reticulated appearance, the lymphoid tissue is much more sparsely scattered throughout the mucosa, and the mucosa itself evinces signs of the most profound changes, looking as though it had been gradually worn away by friction. During the sixth decade the signs of decline are still more obvious, and certainly one would not now be justified in speaking of the appendix as an actively functional lymph gland. With the seventh and eighth decades it is perfectly obvious that the appendix has ceased to be a functional structure (see fig. 7).

We now pass to the third question—"*Is obliteration of the human appendix a physiological process, as affirmed by Ribbert, or a pathological condition as asserted by others?*"

Writing on the Normal Anatomy of the Vermiform Appendix, in Virchow's *Archiv* in 1893, Ribbert came to the same conclusions—as regards the evolution of the lymphoid tissue in the appendix—as we have; but on the present question of the obliteration of the appendix, we part company.

It is well known that it is quite common to meet with partial or complete obliteration of the vermiform appendix (see fig. 10). Ribbert met with it in something like 25 per cent. of his cases, but never saw a case of complete obliteration below the age of 30 years. He seems to regard it as a normal process of involution in an organ in a process of gradual retrogression, and it is on this point that we are compelled to differ from him.

We only found undoubted cases of complete obliteration of the vermiform appendix seven times out of 103 cases, and it will be remembered that all cases where there was any doubt whatsoever about the patient's having suffered from a previous appendicitis were carefully excluded. Of these seven cases, four occurred in females and three in males; and out of the seven, three were in patients below the age of 22. We also regard it as an important point to note, what Ribbert does not note in his paper, the cause of death in these seven cases; thus:—

Case 1.	Female,	age	17.	Cause of	death—	Cardiac disease.
Case 2.	Male,	„	20.	„	„	„ „
Case 3.	„	„	21.	„	„	„ „
Case 4.	Female,	„	40.	„	„	Bright's disease.
Case 5.	Male,	„	45.	„	„	Phthisis.
Case 6.	Female,	„	58.	„	„	Malignant stricture of œsophagus (see fig. 10).
Case 7.	„	„	73.	„	„	Cardiac disease.

These seven cases were all submitted to an expert pathologist, who expressed the opinion that the occlusion was, in every instance, a pathological process—" an interstitial fibrosis, the result of vascular obstruction, and possibly part of a general arterio-sclerotic condition."

In all these cases of obliteration the mucosa of the appendix entirely disappears, the lumen being occluded and occupied by connective tissue; the tubular glands and lymphoid tissue are also entirely suppressed, and the changes generally are so profound that it would be impossible to recognise the section as one of an appendix.

We do not, therefore, regard obliteration of an appendix free from appendicitis as a physiological process of natural involution, as does Ribbert, but as a purely pathological process; and we do so for the following reasons:—

1. Obliteration is not confined to the latter half of life but occurs at all periods, four of our seven instances having been from patients below the age of 30.

2. A progressive examination of appendices from birth up to the most advanced periods of life does not reveal any very great increase in the tendency to obliteration.

3. The cause of death in six out of seven cases involved vascular changes with concomitant backward pressure.

4. Pathological opinion supports the view that all our series of cases of obliteration are undoubtedly pathological in character.

We regard this question of obliteration of the appendix—whether physiological or pathological—as of considerable importance, because if it is physiological in character it tends to strengthen the view that the vermiform appendix is an organ in a state of retrogression, whilst if it is pathological in its origin then that view falls to the ground and the appendix takes its place alongside any other functional organ in the body.

For our part we are firmly convinced, for reasons already adduced, that obliteration of the human appendix is a pathological process, dependent, most frequently, on vascular disorders.

One other important pathological condition falls to be recorded in

connection with the present series of cases, namely, an undoubted example of a foreign body in the appendix. It occurred in a female aged 17 years, and is in all probability an example of the whip-worm or the trichocephalus hominis (see fig. 11)—a surmise which is strengthened by the fact that Metschnikoff in 1901 showed that the tricocephali can produce symptoms resembling those of appendicitis, whilst in the same year Girard actually found the parasites in the appendix producing appendicitis.

These facts in no way invalidate the statement originally made by one of us that the entrance of foreign bodies into the appendix is extremely rare, for there is a great difference between inert matter such as shot and bristles and a living organism like a whip-worm. It is most improbable that inorganic material can pass from cæcum to appendix in anything like large quantities, and extremely likely that living organisms like worms can do so.

Lastly, in framing our conclusions it must be borne in mind that such conclusions are not based solely on the appendix of man, but on what has already been worked out by one of us for the animal kingdom in conjunction with what we now find in the appendix vermiformis of man. The conclusions which we draw from these investigations are as follows:—

1. Lymphoid tissue is the characteristic feature of the true cæcal apex throughout the animal kingdom, including man. As the vertebrate scale is ascended, this tissue tends to be collected together into a specially differentiated portion of the intestinal canal—the vermiform appendix.

2. The amount of lymphoid tissue present at the cæcal apex varies, most probably though not certainly, in accordance with the varying diet of the animal.

3. The vermiform appendix of man is not therefore either a vestigial remnant, or an organ in a state of retrogression, but is an actively functional lymph gland. It is no argument against this view to state that because the appendix is frequently removed without any apparent functional disturbance that it is useless, because the same argument might be adduced against the stomach, which is occasionally removed either wholly or in part and with more or less success.

4. The appendix of man is not equally functional throughout the whole of life. At birth it contains practically no lymphoid tissue; within six weeks it has become a lymph gland and continues as such during the first half of life, after which it progressively declines in functional activity. Lymphoid tissue is therefore a tissue of the growing animal.

5. Obliteration of the vermiform appendix is a pathological process.

6. The functions of the human appendix are the same as those of any other collection of lymphoid tissue in any other part of the body.

EXPERIMENTAL CONTRIBUTION TO A THEORY OF THINKING.

By HENRY J. WATT, M.A., Ph.D., *Carnegie Fellow*.[1]

FOR this thesis a long series of experiments was carried out. *Several hundred nouns* of common occurrence were printed in big type on cards and were shown to the observing subject one at a time by means of an automatic *card-changer* (Dr Ach's). A metal plate, which covered the card, sprang up, when a string was pulled, and by so doing closed an electric current, which flowed through a Hipp *chronoscope* and a *speaking tube* (Cattell's). The chronoscope therefore marked the time which passed from the appearance of the printed word until the first vibrations from the subject's voice broke the current in the speaking tube. This constituted the measure of the duration of the reaction and formed, with a full account of all the reproducible experiences of the observing subject, which were at once written down in full, and any other remarks he had to make, the experimental data of the thesis.

In contrast to previous experiments, on association definite *tasks* (*Aufgaben*) were given, which the subject had to accomplish in the reaction. These referred to what the printed word on the card signified, and were as follows: to classify it, to name an example of it, to name a whole to which it belonged, to name a part, to name another of the same class or another part of the same whole. Each subject performed

[1] This paper, which is to be regarded as an abstract of a thesis entitled, "Experimentelle Beiträge zu einer Theorie des Denkens" (Doctor Dissertation, Würzburg, 1904, *Archiv für die gesamte Psychologie*, vol. iv. Leipzig: Engelmann, 1904. Pp. 154), was accompanied by a letter from the author addressed to Professor M'Kendrick, of which the following is a paragraph:—

"I have made no attempt to sketch a physiological theory which would give a basis for the psychological factors I distinguish in my thesis. It is only just to those who know the possibilities of such physiological theories better than I do, to allow a clear account of psychological analysis to tempt *them* to any such undertaking. In several points, besides, as will be evident to you, my work goes rather to strengthen the hands of those who, for the present, want to work out their physiological material directly without any conclusions from psychological theory. The most we psychologists can hope meanwhile is, that some analysis of ours may suggest a new idea to some physiologist which he might try and investigate directly on physiological material. That would be something to be proud of! It will also be good if the impression gains ground that experimental psychology is an intelligible and exact science and not a mere play with dreams."

the experiments separately, and every care was taken, both in regard to technical details and to the way the experiments were carried out, that no disturbing factors should be present. The most of the work was done by four practised observers, and over three thousand experiments were made in all.

The following are *the results*. In almost every case the subject is able to accomplish his task correctly. His description of his experiences shows that there are in the main *three kinds of complexes of experiences*. Most frequently the subject follows one line right through the experiment, which then leads to the spoken word. In the other cases, he may seek a word which he does not find, and which he even afterwards cannot name, or he may have intended to say a certain word, but for some reason or other, wittingly or unwittingly, have said another. In general the first class, the *simple reproductions*, take place in a good deal less time than the other two classes, the *complex reproductions*, of which two the second named usually and naturally last longer.

Within each of these classes there are *three groups*. In the *first* of these the spoken word follows directly on the given optical stimulus, sometimes after a pause which can be described in no particularly definite way, sometimes with the assurance of the subject that between the stimulus and the reaction nothing whatever has been experienced. Such a reaction lasts in general a very short time, and in the second form a shorter time than any other kind of association reaction. In a *second* and very large class, a *visual representation* follows the stimulus. Directly after that, or after a short pause or a so-called search, comes the spoken word. These are a good deal longer than the first set, and sometimes longer, sometimes shorter, among themselves according to the detail and vividness of the representation and the frequency of occurrence of such reactions containing visual representations for the particular subject. *Last* of all come those reactions in which a *word-representation*, or some experience which could only be described in conceptual terms and not analytically according to its psychological content—call it a thought—appeared between the presentation of the word and the spoken reaction. These were often shorter than those containing visual representations and sometimes longer. It is not, however, contended in this classification that the reaction could take no other course. On the contrary, it is easy to see that we could have tone, smell, taste, touch and other such representations playing a part in the reaction, provided the conditions of experiment produced them. None of these were clearly present among these experiments.

But what are these *conditions of experiment*? How does any one particular reaction come about and not another? The *first influence* at

work on the subject is the given *task*. This he hears spoken by the experimenter, and generally repeats to himself in words, *e.g.* "find a part!" "name an example!" or he may exemplify the experiment to himself, *e.g.* "animal—dog," and so on. The scanty description of the preparation for the experiment given in the subject's account of it does not help us to form a very clear idea of what the process itself is. It was found, however, as a series of detailed curves show, that of all the simple reproductions the percentage of occurrence of each of the three above-named classes changes regularly and similarly with each subject from one task to another. This leads to the assertion that the task has a regular influence on the *nature* of the experiences of each subject, which becomes particularly evident between the two larger groups of simple reproductions, those containing visual representations and those containing nothing at all. The change of task has a most decisive influence on the percentage of these classes, and a subject who has hardly a single visual representation when the task "classify" is given, may have them in 50 per cent. of the cases when the task "find a part" is given. Alongside this, a subject with 50 per cent. visual representations in the first case, may have 90–100 per cent. in the second. Moreover it is found that the *duration* of the reaction in each of these classes is also on the average dependent on the nature of the task. So too is the duration of the complex reproductions, but the percentage occurrence of these, out of all experiments made, is, curiously enough, quite *independent* of the nature of the task, as curves show. The attempt is made to explain this by a fairly probable consideration. The number of tendencies to reproduction which diverge from any one stimulus, must depend on the number of ideas with which the stimulus is associated. It is impossible to conceive how the task should change these, as an association must be presupposed before the task working with the stimulus could produce any reaction. The occurrence of a complex reproduction would depend then on the nature of the stimulus-word given and not on that of the task. The influence of the *task* has therefore to be carefully differentiated from that of the *stimulus*.

An analysis of the experiments worked with the fifth and sixth tasks shows that an experience which plays an *important* part in producing or leading to a reaction makes the reaction longer than when the experience only comes along with the stimulus or the reaction-word, that is, when it is only side-play, as it were.

States of consciousness *tend to persist* and to return more easily once they have been experienced. It is found that they come *more rapidly* after the first time. It is found, besides, that the task also tends to persist, for it also often comes to consciousness, in the form of a word-presentation

or the like, during the course of the experiment. In the great majority of cases this occurs only where some disturbing factor has been present, while the normal reproduction runs its course smoothly from beginning to end, as soon as the regular preparation for the experiment, *i.e.* the given task, has worked on the stimulus without any repetition during the experiment. The *repetition of the task* is therefore, we suppose, made necessary as soon as the task ceases to operate sufficiently well. This shows the exchange which goes on between representations and the task in operation. A suitable representation may introduce the task, which then, when it has ceased to operate effectually, may come to consciousness in similar representations. By means of such exchange it is possible to modify, strengthen, restrain, or check the task which is operating.

It has already been shown in experimental work on memory that the *rapidity of a reproduction* is dependent on the number of times the reproduction has occurred. In accordance with this it is found that the rapidity of such reproductions as those here described is dependent to a very large degree on the number of subjects who make any particular reproduction. The dependence is, of course, not supposed to be direct, but the co-ordination and the result presupposes that the number of subjects who make any given reproduction is a fair sign of the frequency of its repetition.

The result is very distinct and the exceptions can, as a rule, be explained by the record the subject gave of his experiences or by other experimental data. Further, if the average duration of each grade of frequency is co-ordinated with the change in the task for each subject, the *influence of the task* on the duration of the reaction *in each grade of frequency* is seen to be surprisingly similar to its influence in the previous cases. This means that the influence of the task is *independent* of the rapidity of the tendency to reproduction in itself, so that the influence of the stimulus-word is for the second time differentiated from that of the task. It is, then, probable that the rapidity of a tendency to reproduction from one point to another in the stream of succeeding ideas is something by itself, independent of the influence of the task operating at the moment. Whether the latter be to the increase of the former in every case remains to be settled.

It has often been asserted that over and above more or less mechanical reproductions, which are often to be found in our mental experience, there is a large number of cases in which the decision is not uniformly and completely determined by regular laws, but in which a greater or less amount of scope is allowed for the usually indefinite activity called choice or selection by the attention and the like. But a thorough examination of the complex reproductions, in which no particular description was given of

the second tendency to reproduction, produces a large mass of evidence, partly from the record of the subject and partly from manifold combinations of the various experimental data, much too detailed to be described, in favour of the reproduction which actually took place. This shows that, if other conditions remain the same, it is the individual strength or *rapidity* of the tendency to reproduction *which determines the reproduction,* and not anything else. In other words, the influence of the task is the same for all the reproductions it makes possible. It is not meant, of course, that our everyday conception of choice has no meaning, but only that the influences which determine every event in our mental experience fall into two large groups, the operating task and the individual strength of the reproductions which come thereby in question. On the one hand, the task may find no reproductions, in which case no reaction can occur; and, on the other hand, the strength of the tendency to reproduction may be too great for the task to operate, in which case it forces its way out in spite of the task, or before any reproduction which the task favours has had time to become actual: in other words, a wrong reaction takes place. Otherwise, more or less suitable reactions occur. This is thought to be *valid for the whole of our mental experience,* because the very few cases which offered no explanation, contained no indication of any other determining factors, and are therefore to be placed alongside the others with the remark that in these cases the record of the subject or the experimental data were probably deficient, as can always occur in such experiments.

A detailed examination shows further that the general content, the vividness, and the frequency of our *visual representations* is dependent on the nature of the *task* in question. It is therefore probable that rather hasty generalisations have been made of the possible *types of mental imagery.* It could very well be, according to this result, that a subject who showed an entire absence of visual representation with the kind of task which has hitherto been given to determine the types of mental imagery, would with other tasks show quite a lively and detailed visual imagination. An example of almost such a case occurred among the subjects used for these experiments. It is probable, however, that one who has fewer and less vivid imagery than another with one task, will with another task again have less vivid and detailed imagery than the other.

The attempt to establish an *association by contrast* or by *similarity* is then discussed, on the basis of the experiments, and is rejected, because it is found to be impossible to show that similarity as such could determine an association. Apparent determinations of reproductions by similarity are found to dissolve into more detailed reproductions, which are themselves

determined by the factors already discovered. There is no reason to expect that the subject in his record should be able to give the reason for any reaction, or even always the previous mental experience by which the reproduction in question under the operation of the task was determined.

A detailed examination of the experiments with each task by themselves, leads to interesting results which tend to separate the task as a psychological factor still more from the tendency to reproduction in itself and from other factors. Interesting connections are shown between the logical relations contained in the tasks given and the psychological processes found in the experiments, in which the psychological simplicity and rapidity of happening are shown to be sometimes on the side of the logical simplicity and sometimes not.

In a lengthy *summary* the results are brought together under various points of view and several *theories* formulated.

After a short summary of *individual differences*, a *criticism of the distinction between motor and sensory reaction* is given. First of all, the facts are brought together to show that this distinction is a fairly good description of some differences between the subjects. The first basis of the distinction was the usual arithmetical mean, but of late it has been thought that the *curve of distribution* of the reaction-times gives a better foundation. This curve is formed by making a time equal to the probable error of all time-observations of the series the unit in the horizontal, and by setting the number of cases which occur at each such unit on the perpendicular. If the number of factors involved is small and limited, then this curve ought to rise to one or more symmetrical points. This is sometimes the case, especially in the motor reaction, according to the latest researches. It is evident, according to the last two of these, that the time of even the motor reaction can be shortened a good deal with practice, and the curves seem to show points at somewhat regular periods,—these periods being, however, liable to minimal displacements when the nature or quantity of the stimulus is changed. It is also indisputably true, that the *class* to which any experiment is to be reckoned, is not determined by the nature of the experiment after it has been made, but by the nature of the given *preparation*, the direction of the attention to sensory or motor elements. Here, then, we have again differences between what we call the task and the mere tendency to reproduction or any physiological basis for the latter. A *motor reaction* is, therefore, merely the quickest and most constant reaction possible, which constancy and rapidity are achieved by simple and constant conditions of experiment and of task especially. The long-practised so-called *natural reaction*, in which the task directs the attention specially neither to the stimulus nor to the movement which is

to be carried out, also shows a regular curve of distribution. It is evident that in this natural reaction, too, the factors involved are constant and regular. The *sensory reaction*, however, is not nearly so liable to be regular, and it is supposed that this lies in the *greater complexity of factors*, because the curve of distribution contains not one, but several high points. This is made probable by its being shown that, in the curves of distribution of the experiments made, the average times of most of the big classes of experiments found and distinguished on the basis of the records, lie under the larger rises, and *vice versa*. It is then likely that, if the conditions could be kept as constant as they are in the shortest possible reactions, the curves of distribution would be quite as regular for any set of conditions whatever. Peculiarities in the form of the curve of distribution would then be *symptomatic* of peculiarities in the reactions or in the factors which bring about these, and thereby an aid to discovery. The distinction between sensory and motor reactions is, therefore, *not physiological but psychological* in the prime instance, and is not an exact distinction. It has to be split up into its elements, and when this is done nothing new is found.

This result leads to a more decisive way of looking at those reactions which, through frequent repetition, are held by many to become *unconscious* or *mechanical*. It is evident that, if reflexes be excluded from this class, a task is always necessarily presupposed for the accomplishment of such a reaction. The task may not have been given before each experiment, but it must at least have become operative. The stimulus is given and the reaction follows without any conscious links intervening whatsoever. There is no need to appeal to the unconscious even when everything else falls away except the essentials, task and stimulus.

The *method of subtraction* of different sets of reactions from one another, in order to find the duration of an act of recognition, of distinction, and of association, is subjected to a criticism. In order to find the duration of elementary acts, it is no guarantee to suppose that the contents of all experiments carried out with the same task are the same. First of all, those experiments which are really similarly composed, must be collected with the help of the experimental data and the records. An ideally complete reaction, made up of bits out of many different reactions, is of no use for this purpose. The scheme which has been the basis of this method of subtraction is, besides, very mechanical, much too mechanical for any one to suppose it to be based on data which are true, or likely to be found true in physiology. But even if the number and nature of the elements in an experiment were experimentally determined, it has to be remembered that it is not yet settled how exactly the task affects each element which goes

to make up the reaction. All this does not make the method impossible, but only for a long time purposeless.

If *association* be understood as the cause of the known fact and experience of reproduction, it may be *defined* as that by means of which it first becomes possible for one experience to be reproduced by another. Other definitions are found to rest on logical divisions, and to give no guarantee of unity in research. There can be only one kind of association, as far as we know, and on the basis of the previous results the later experience is never reproduced by the earlier by means of the *value* of the logical relations between them but only by the factors described above. The only conceivable condition for the origin of association is, that the two experiences shall have once been together or immediately successive in consciousness.

It is evident that, to form a *judgment*, the subject must have at the moment some experience, and, besides, some experience which consists of reproductions, because an absolutely new experience and nothing else could not be held to form a judgment by itself. An absolutely fixed and rigid system of reproductions, however, gives no judgments, but merely a succession of experiences under the one principle of association. Even the subjects themselves tend to decline the responsibility for judgments in which the reaction which constituted the judgment was determined by the overwhelming strength of a tendency to reproduction. The experimental conclusion drawn by Marbe is accepted, that if one confines oneself to the experiences between the stimulus and the reaction, there is no psychological criterion of the judgment. Outside of this limit, however, stands the *task* which, even if it is not identical in the sense of being always either visual representation or word-representation or the like, is yet *functionally identical*, and is the one factor which goes beyond the rigidity which the single tie of association would give. *The operation of a task makes the reaction* which is determined by or in spite of it, *a judgment* in reference to this task. This position must be met before the attempt can be made to set up hidden unconscious or rare experiences as the criterion of the judgment. It is also evident that the agreement of ideas with their objects, whether these be themselves ideas or not, can never be directly the aim in view. Such agreement, if it exists, can be only and merely the result of the operation of the factors enumerated, of which the one, the task, may of course include the conception agreement. For how would it be possible to proceed to obtain such agreement psychologically?

A *theory of thinking* has, then, to start from our experience as we know it. This presents to us no sharply defined states with beginning and end like printed letters, but only continued observation leads us to a more and

more detailed and exact description of our experiences. By means of experimental data we can work ourselves out beyond this position and formulate our factors more precisely. We decline to accept choice and apperception or contrast and similarity as exact or useful scientific conceptions any further. The tendency to reproduction which realises itself, *ceteris paribus*, is that one which, by reason of more frequent actualisation, possesses a greater speed of reproduction. The task, which is no doubt itself a wider and stronger tendency to reproduction, has been sketched in detail as an operative force, and its sphere of operation is doubtless much larger than we have been able to determine it to be. Over against any tendency to reproduction, the task can only overpower a limited amount of force, a circumstance which makes false reactions possible. Any theory of association which operates only with associations between two experiences immediately following one another, is thus seen to be insufficient, though this much must be presupposed in any theory. Physiology can, perhaps, not offer us more than this at present, but a more exact definition of psychological factors and their sphere of operation can only be welcome to physiology, while the prospect that physiology and psychology will one day be able to give an account of their material which they will find to be much more intelligible to one another than it is now, is by no means excluded. It seems probable at present that the *variable factor* is the strength or rapidity of reproduction and *not the task*, which is supposed to favour in equal strength all tendencies to reproduction which come under its influence. The operations of these two classes of factors on one another, which seems to be confined to a small area which contains at least our fully conscious experiences, is what we know as thinking.

It must not be supposed that the picture of his mental experience given in a subject's record is by any means complete. We see from these results that besides mere suppression of parts of a record, which is not presupposed, the subject may have forgotten something, or the tendencies to reproduction and the tasks which would have enabled him to give a full and accurate record may not have been present, or, for want of practice, very poorly developed. Even if forgetfulness is put aside, we have therefore no right to suppose that what is not in the record was not experienced. But granting this, what can we say about that part of experience which does not come fully to consciousness in reproductions and judgments? A mere mechanical succession of events in consciousness seems to us obviously intelligible, as soon as it happens in fact. What we do not understand is the *meaning* contained in the reference of one experience to another, whether it reproduce or be reproduced by this other. The reaction refers to the stimulus, and, under the influence of the task, brings to fuller consciousness

something which was latent in it, although, as we have seen, no other fully conscious elements need be found either in the record or by experimental investigation. There are, besides, several elementary experiences which cannot be further analysed into psychological components, but can only be rendered by one or many reproductions. Such experiences are the more indefinite conceptual states of consciousness, what is often called feeling (other than pleasure and pain). Such experiences may besides be introduced by representations, for example, word-representations, and they are then to be exemplified by conceptions and tasks. All this points to an *insufficiency of consciousness* to give a full knowledge of our subjective experience. The only means we possess for supplementing this deficiency, is to contrive that every part of our consciousness shall be operated on by tasks capable of bringing as much as possible to full consciousness in reactions or judgments. At the same time, this conception of the insufficiency of consciousness starts out from conscious experience and does not necessarily imply notions like the *unconscious*, which lie further afield and are as yet more or less indefinite and unsettled. The *great advantage of the experimental method* is, that it enables us, by grouping of data and by a more exact knowledge of the elementary factors of experience, to overcome the insufficiency of our direct introspection.

The thesis closes with a critical discussion of general representations and conceptions.

ON SOME MINOR MARKINGS ON BONES. By J. ERNEST FRAZER, F.R.C.S., *Senior Demonstrator of Anatomy at St George's Hospital.*

IN endeavouring to estimate the causes that lead to the production of ridges and rough markings on bones, it is necessary first of all to divide these into two main classes, which may, for convenience, be termed *primary* and *secondary*. In the first group may be placed all "margins" of surfaces that are evidently due to the architecture of the bone; for instance, the inner margin of the shaft of the femur, or the anterior margin of the lower half of the shaft of the humerus, are plainly concerned with nothing but the shape and mechanical functions of the bones, whereas the linea aspera or the supra-condylar ridges of these bones are as evidently connected with the attachment of structures to them.

I propose in this paper to deal with the *secondary* group of markings only, and to preface my remarks with the statement that muscular fibres which reach the bone do not leave any marking upon it which can be seen in the dry state, from which it follows that the ridges and markings on bones are caused by the attachment of other (fibrous) structures, *i.e.* of tendons, ligaments, aponeuroses, and fasciæ.

Another point would be, that where a muscle is said to be "marked" naturally on a bone, the statement is necessarily a loose one, and probably inaccurate, for the "marking" would be due either to its containing fascia or aponeurosis, or to its complete or partial tendinous nature; in the former case the true muscle marking would be contained in the so-called "marking" and might not even quite correspond with it, while in the latter case the true muscle marking would cover and include the natural "marking."

The margins of surfaces of bones are lines taken for descriptive convenience, and a margin of this sort may correspond only to a *primary* ridge, as in the margins of the anterior aspect of the femur, or may be only indicated by a *secondary* line, as in the outer margin of the ulna, or by a combination of the two, as (perhaps) in the linea aspera or the inner margin of the tibia: the posterior edge of the internal pterygoid plate is perhaps an example of a *primary* margin with a *secondary* Eustachian spine on it.

Articular processes are of course *primary*, as the trochlea or the acetabular margin, but may bear *secondary* markings, as for the cotyloid ligament on the acetabular margin.

The amount of marking caused by these fibrous attachments seems to vary more or less with the thickness of the structures concerned, but this is not an absolutely constant rule, and perhaps the connection may be an indirect one,—for instance, the thickness of a structure might more or less vary with the amount of strain it has to undergo, and as the ridges, etc., are probably caused by a slight spread of ossification into the fibrous tissue, those that have a little more ossification might be by that means more firmly attached and so better able to hold under greater strain.

However this may be, it is a fact that structures apparently of approximately the same density and extent have markings of widely different accentuation, and many exceedingly thick ligaments have places of attachment with rough margins but smooth included surfaces.

Without dwelling further on these general points—beyond saying that probably every fibrous structure that reaches a bone has a corresponding marking—I will proceed to describe certain markings on the bones of the skeleton in some detail, but as shortly as possible, not dealing with the markings caused by capsular ligaments unless it is necessary, and pointing out, before commencing the description, that the fingers are often of more use than the eyes in following out lines and ridges on bones.

FEMUR.

This bone does not require a long description, as, with the exception of markings for articular structures, it does not present many lines calling for detailed consideration.

The linea aspera is possibly really a primary margin covered by marked secondary ridges: its description, as composed of two "lips," is only accurate in a general way, and, if a series of femora are examined, indications of the component lines forming it and corresponding to the various tendons reaching the bone may be found in many places. For instance, the pectineal line may be more or less apparent, and that for the external intermuscular septum is often clear, while that for the adductor magnus can sometimes be traced for almost the whole or part of its extent, being thickened and obscured internally at places that seem to correspond with the insertion of the other adductors: yet, taken as a whole, the region is certainly confused, and its component parts need only be considered where they emerge from the compound linea.

The external intermuscular septum is part of the insertion of the gluteus maximus, and does not reach the lower end of the bone. If the outer border of the popliteal surface is examined, there is usually to be found a small elevation or tubercle on it, about a couple of inches or so above the

condyle (A, fig. 1), which marks the attachment of the lowest fibres of the septum, and has a depression just above it, where a large muscular artery pierces the septum to pass under the vastus externus.

This muscle does not take origin lower than the point of passage of the artery, but lies in front of the septum, with which its fascia is blended, and below the position of the tubercle that marks the end of the septum, the fascia is continued on, still attached to bone, but following the margin of

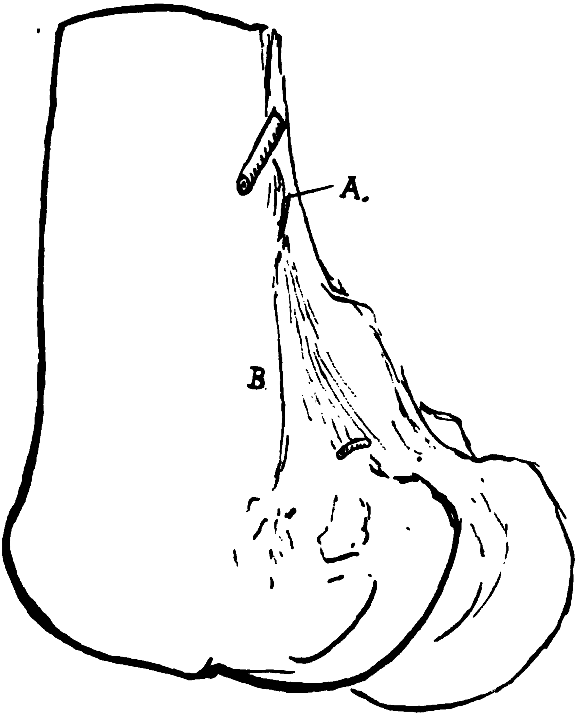


FIG. 1.

the muscle, so that a secondary line (B) is formed on the bone, running downwards and perhaps a little forwards from the front of the lower end of the tubercle: the line is not always apparent, but an indication of it can usually be found. Below the small tubercle, the margin of this surface is a rounded "primary" margin, but there may be secondary markings on it: in the upper part, just below the tubercle, the marking may be the fascial line standing further back than usual, while in the lower part, just above the condyle, there may be a roughness for the attachment of a fibrous band often found extending from the bone to the gastrocnemius and plantaris.

The bone from which fig. 1 was drawn showed no sign of attachment of this fibrous structure, which lies above the position of the articular vessels and may represent the original attachment of the muscular fibres before they shifted downwards on to the capsule: where the roughness is present, there is usually a smooth surface below it for the articular vessels.

The inner head of the gastrocnemius has a much more extensive bony origin, and leads in consequence to a well-marked roughness along the inner margin of the surface, which has the marking for the adductor magnus lying to its inner side, sometimes altogether in front of the prominent 'margin' itself. This adductor line, leading to the adductor tubercle, shows intensity of marking corresponding to the nature of the structures attached to it: in its upper part, in the neighbourhood of the opening, it is badly marked, as it is only a thin muscle-fascia that reaches the bone here, but a little lower down it becomes a definite line once more, indicating the insertion of the aponeurotic expansion from the tendon of the posterior part of the muscle.

The other markings on this bone do not call for detailed examination, as they are evident and simple. I would like, however, to call attention here to the smoothness of the back aspect of the neck of the bone compared with the front, for the difference seems to me to depend on the presence of recurrent fibres from the front part of the capsule and their absence behind: as they are derived from transverse fibres, and as these are not present posteriorly, their absence behind is accounted for, and this explanation also accounts for the absence of a posterior marking corresponding to the intertrochanteric line in front.

TIBIA AND FIBULA.

The anterior margin of the tibia, for the attachment of the deep fascial aponeurosis, can be traced downwards as a faint but easily felt line to the inner part of the front of the malleolus. Here it is rather better marked, giving attachment to the upper fibres of the annular ligament, and lying about $\frac{1}{3}$–$\frac{1}{2}$ inch inside the inner margin of the tendon of tibialis anticus.

In its upper part the margin has the *tubercle*, but before reaching this the line of aponeurotic insertion goes a little outwards, passing up to the outer side of the tubercle, and so reaching the upper part of the bone a little distance outside and behind the capsular attachment (fig. 2). The line turns backwards here and divides into two more or less well-marked ridges, which are lost in the neighbourhood of the fibular facet, so enclosing a surface for fibres of the *extensor longus digitorum* and *peroneus longus*, which come off the tibio-fibular ligaments on to this part of the tibia; this

enclosed space is subdivided by a vertical ridge (E) into two, the anterior triangular surface being for the former muscle.

The peroneus longus extends from the head of the fibula on to the ligaments (including the external lateral ligament which lies just behind its tibial surface), and so on to the tibia in front, and it is here covered by a forward expansion from the biceps tendon which blends with the fascia covering the muscle. It is therefore evident that the upper line A B marks the insertion of the deep fascia and the biceps expansion, and is lost behind in the roughnesses for attachment of the upper anterior tibio-fibular ligaments.

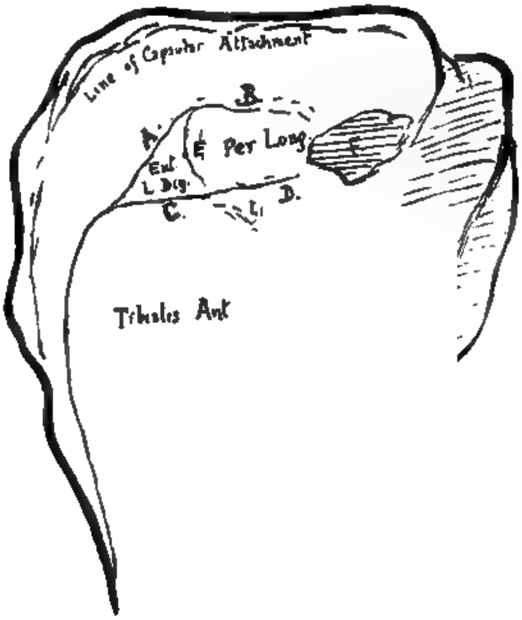


Fig. 2.

In the same way the line E corresponds with the septum between the peroneus and long extensor (anterior peroneal septum) and meets the ligaments below, as they are attached to D, and to a ridge leading down from the junction of D and E; the line C, for the septum between tibialis anticus and extensor longus, leads to the same point, as the septum in its upper part is attached to the fibula and so on the ligaments to the tibia.

Below the fibular facet the roughnesses for ligaments are very badly marked and hard to distinguish, if they are present, from those due to the upper fibres of the interosseous membrane, if these are present. The lower ligaments of this joint are variable, but as a rule slight, and the

membrane usually becomes fascial here, which facts may account for the varieties; the membrane has also a peculiar disposition on the fibula here, which will be described later.

The interosseous ridge on the tibia varies very much in position in its upper part; the two figures (figs. 2 and 3) show a marked difference in this feature, for in the first the line is much further from the tubercle than in the second, giving in the latter a much more extensive tibial origin for the *tibialis posticus*, and correspondingly less for the *tibialis anticus*. In the

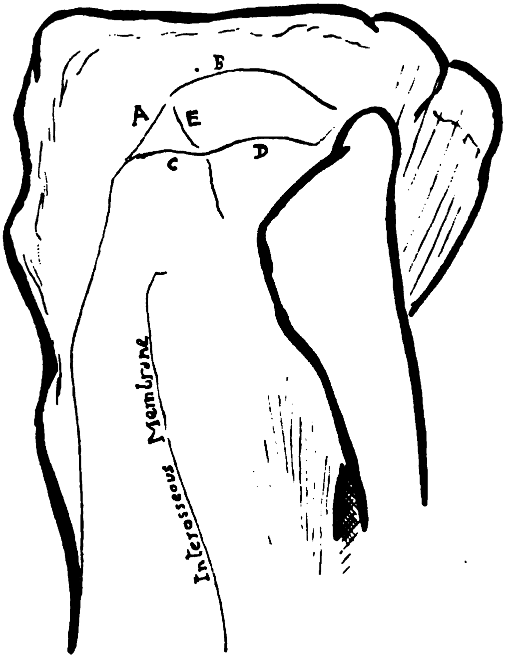


FIG. 3.

former case also there appears to have been a definite membranous attachment leading up to the lower ligaments, whereas in the second case the ridge shows a backward turn and is then lost; as a matter of fact, in this case the upper part of the interosseous space was filled with fatty and areolar tissue, and only a thin fascial connection could with difficulty be demonstrated over the top of the posterior tibialis between its covering aponeurosis and the membrane.

The little rough tuberculated spot marked F in fig. 2 is probably due to the former attachment of fibres from the included tendon of the *tibialis posticus* blending with or lying on the posterior surface of the interosseous

membrane; I have found such bands attached to such roughnesses in other specimens.

The front and inner aspects of the upper end of the fibula have corresponding markings (fig. 4).

The "interosseous border" is continued up to the inner part of the front aspect of the expanded "head," and, as it reaches it, it divides into

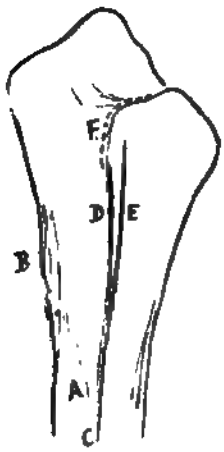


FIG. 4.

FIG. 5.

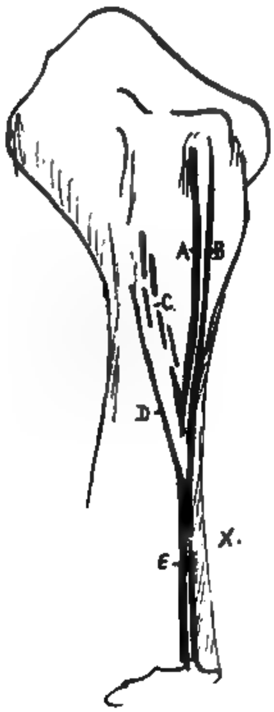


FIG. 6.

two, D and E, the former for the extensor-tibial septum and the latter for the anterior peroneal septum, a slight groove usually separating the two lines and giving origin to extensor fibres. The two septa pass from the head of the bone on to the ligaments, the anterior and upper fibres of which are attached in the situation of the dotted line F.

The anterior tibial artery runs forwards and downwards next to the fibula, rather above and not so obliquely as the oblique line generally seen on the inner aspect of the bone in this situation; the figure (fig. 5) shows the artery lying in position, A marking the oblique line. This line or

ridge is usually very apparent, and runs upwards and backwards from the top of the most marked part of the interosseous ridge towards the rough surface B.

The interosseous membrane is attached to the "interosseous ridge" in the interrupted line C, passing thence to the oblique ridge, and so is inserted into the bone below and behind the artery; but some fibres pass over the artery, and seem to be attached to the bone more or less in the continuation of the "interosseous ridge" upwards (as shown by the dotted line), but in reality they turn backwards, lying on the bone, between it and the upper fibres of the tibialis posticus, and are attached to the rough surface at B.

Ligamentous markings on the inner side of the bone are feeble, as on the tibia.

Outside E the bone is covered by peroneus longus, which is muscular and so causes no markings.

The extensor-tibial septum, traced down, seems usually to run on to the membrane above the place where the artery appears in front, so that the vessel is covered by the fibres of the extensor and passes under an arch in the septum, on the membrane, to get into its position internal to the muscle.

The anterior tibial nerve comes through the anterior peroneal septum lower down, and often causes a depression in the marking, but fibres go under the nerve, and so the depression may not be present, but the line for the septum is generally more marked below the position of the nerve foramen.

The diagram (fig. 6) is intended to give an idea of what seems to me to be the plan of arrangement of attachments in this locality; the bone is supposed to be seen from the inner side and somewhat in front. A is the extensor-tibial line joining the upper fibres (C) of the interosseous membrane just above the point of passage of the artery. D is the line of fibres of membrane just below the artery, and E the line common to the membrane and the septum. B is the anterior peroneal line, showing a depression at X for the anterior tibial nerve.

On the inner side of the tibia, just in front of the inner margin, is the marking for the internal lateral ligament, and, occasionally, an indistinct marking round this for the tendons of sartorius, etc. Very frequently it does not seem to be possible to trace the markings of these tendons (though they can sometimes be felt, if not seen), and they are a good example of the absence of direct relation between the accentuation of markings and the size and strength of the structures causing them. The feebleness of the marking may in this case perhaps be connected with the direction of the tendons as they reach the bone, enabling them to get an extensive and

powerful hold on the periosteum, without tending to pull it from the bone and so calling for a stronger attachment.

The posterior tibio-fibular region shows simple lines related to the fibrous attachments. The most complex is the "oblique line" on the

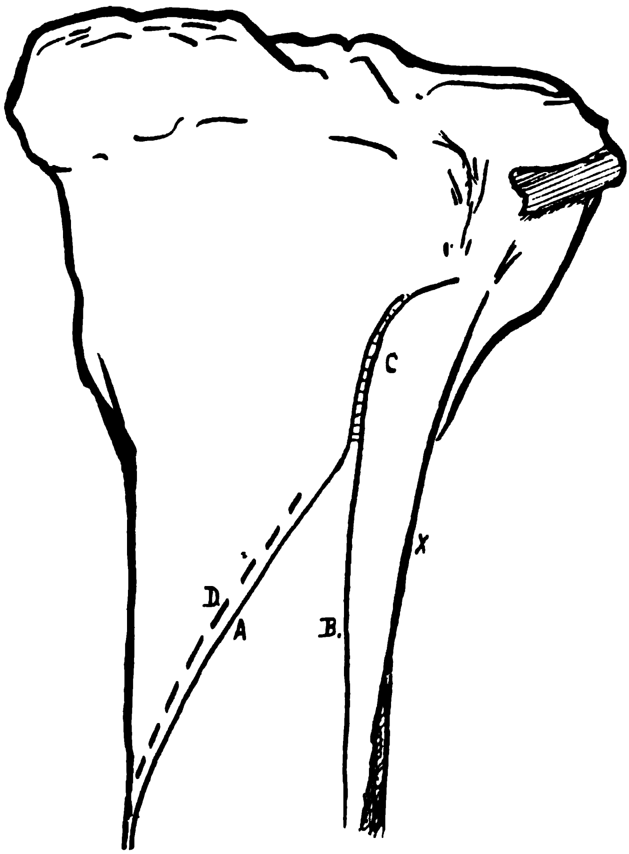


Fig. 7.

tibia, from which the soleus is said to arise. The composition of this line is perhaps best explained by reference to the diagram (fig. 7). The line A represents the attachment of the *deep transverse fascia* and deep aponeurotic fibres of the soleus;[1] as it passes upwards it meets the line of attach-

[1] I have found it hard in most cases to distinguish between these structures in this part of the leg; they are blended, and the separation from the point of view of this paper is not of importance, so I shall use the term "deep transverse fascia" as including the other fibres where these are present.

ment (B) of the aponeurosis covering tibialis posticus, and the two layers blending slightly are continued up in the region of C.

B ultimately tends to blend with the interosseous membrane which is attached to X, but as this blending is usually a thin fascial one, there is no marking on the bone.

The interrupted line D represents the insertion of the lower expansion from the semimembranosus, which does not extend so far outwards as the line of the popliteal vessels; its lower innermost fibres blend with the internal lateral ligament at, and just above, its insertion, while above this they reach the inner margin of the bone and still higher lie, with their tendon of origin and just below it, under cover of the ligament, a bursa interposing.

So "the oblique line" really consists of three or more parts, but, although this plan seems to me to represent the underlying arrangement, as it were, there are several matters of fact to be borne in mind in interpreting the value of the line as usually found; in the first place, the expansion consists largely of separate tendinous bands, producing a tuberculated appearance on the bone, and the same may be said of parts of the "transverse fascia." Moreover, the expansion frequently is continuous at one or more points with the fascia, and there is usually some interlacement of the fibres, or the expansion may continue under the fascia to run into the flexor longus digitorum. The upper fibres of the "transverse fascia," which run down to loop over the vessels, etc., are usually placed in bands, and this part of the line in consequence not infrequently is markedly tuberculated.

As a result of these factors the appearance of the line varies much, and its want of definition is increased by the fact that the lower and deep fibres of the popliteus may be tendinous in parts, and so lead to a bony roughness above the situation of the line proper; it is also apparent that, under these conditions, the direct origin of the soleus from the bone is improbable and often impossible, except by means of the "transverse fascia"; in fact I have dissected a leg in which the soleus got no origin at all from this part of the bone, as the expansion ran under an arch of the deep "transverse fascia" to be directly continuous with the covering of the long flexor.

In this specimen, when the soft parts and periosteum were removed, the line was found to be apparently formed as in the diagram (fig. 8). A was a single line formed by insertion of deep fibres of the semimembranosus expansion; only the superficial ones were continued over the flexor longus digitorum. C is the ordinary "vertical line," and in its upper part, where it forms part of the oblique line, it seemed to be reinforced by another line B, caused by the upper fibres of the "transverse fascia"; the lower fibres of this fascia formed a ridge again at D, the interval between representing the position of the arch passing over the downward continuation of the expansion.

The figure represents in a diagrammatic form what seemed to me to be the distinct result of carefully tracing the lines and attachments.

The covering aponeurosis of tibialis posticus ends below, at the end of the line, by becoming directly continuous with the fascial sheath of the tendon; so there is no line on the tibia. The corresponding line on the fibula runs into the interosseous ridge, showing the junction of the aponeurosis with the membrane below and outside the muscle. The bony origin of the muscle is thus marked out with great accuracy by the lines of its covering aponeurosis, but there are additional markings on the included surfaces; the best known of these is the oblique line on the fibula running downwards and forwards and not always present. This seems to be caused by the origin of a tendinous septum in the muscle; and other slighter markings, owning the same causation, may be found on both bones.

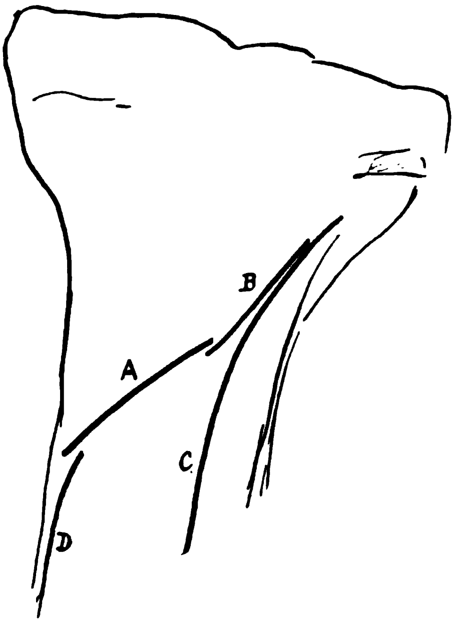


Fig. 8.

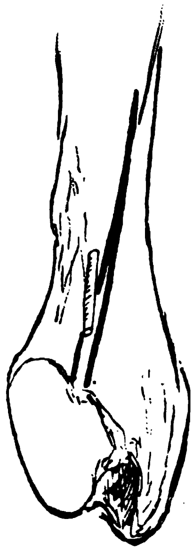


Fig. 9.

The upper oblique line running downwards and forwards has already been described, and is one of the limits of the muscle origin.

Foot.

The lines traced downwards on the two bones are very simple; the ridge for the transverse fascia and the deep fascia of the leg runs down the

inner border of the bone below the origin of soleus (with rarely a depression for a communicating vein), and so reaches the inner border of the malleolus, where it is better marked as the fibres thicken for the annular ligament. From this point it is continued across the lateral ligament, with which the annular fibres blend, to the tuberosity of the scaphoid, turns down along the front of this and, blending with the lower fibres of the Y-shaped anterior ligament, these two layers are inserted in a common line going under the inner part of the inner cuneiform and so to the lower border of the first metatarsal.

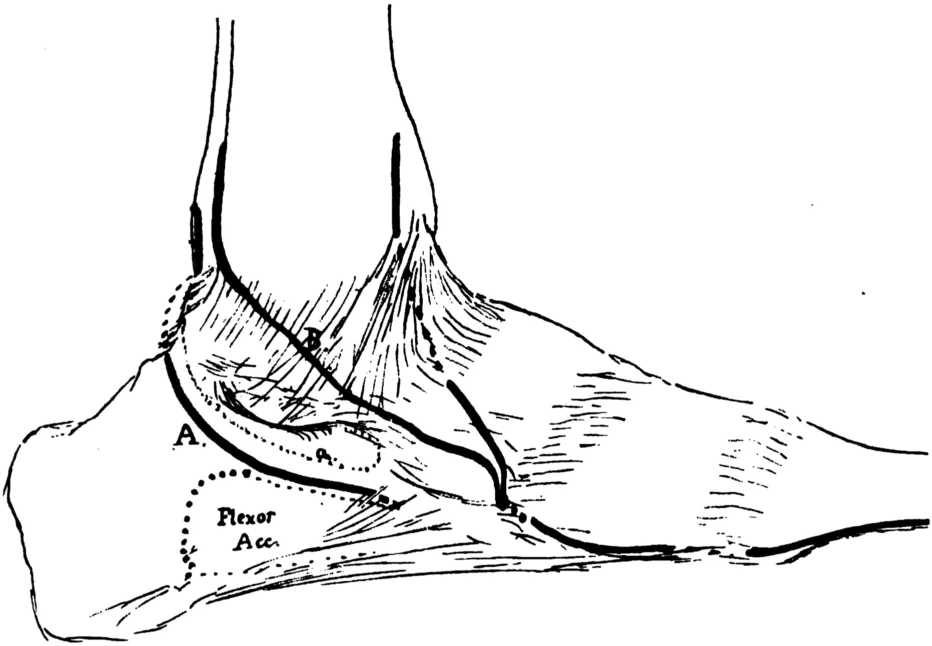


FIG. 10.

The two figures of the foot show the position of the lines of attachment of the fasciæ; it will be noticed that whereas the line just dealt with is continued over the ligaments of the ankle, the others are interrupted here, a method adopted to call attention to the fact that in the former case the fibres of the annular ligament lie on and blend with the lateral ligament, but in the latter there is a tendency for the line to be broken and incomplete, the resulting openings being filled with fatty tissue continuous on the one hand with that under the lining synovial sheaths, and on the other with that outside the fasciæ. The same tendency is exhibited when the lines cross the smaller ligaments.

The outer line of the transverse fascia in the leg corresponds with that of the peroneo-flexor (posterior peroneal) septum, and the two may run together to the lower end of the outer malleolus, but occasionally the line

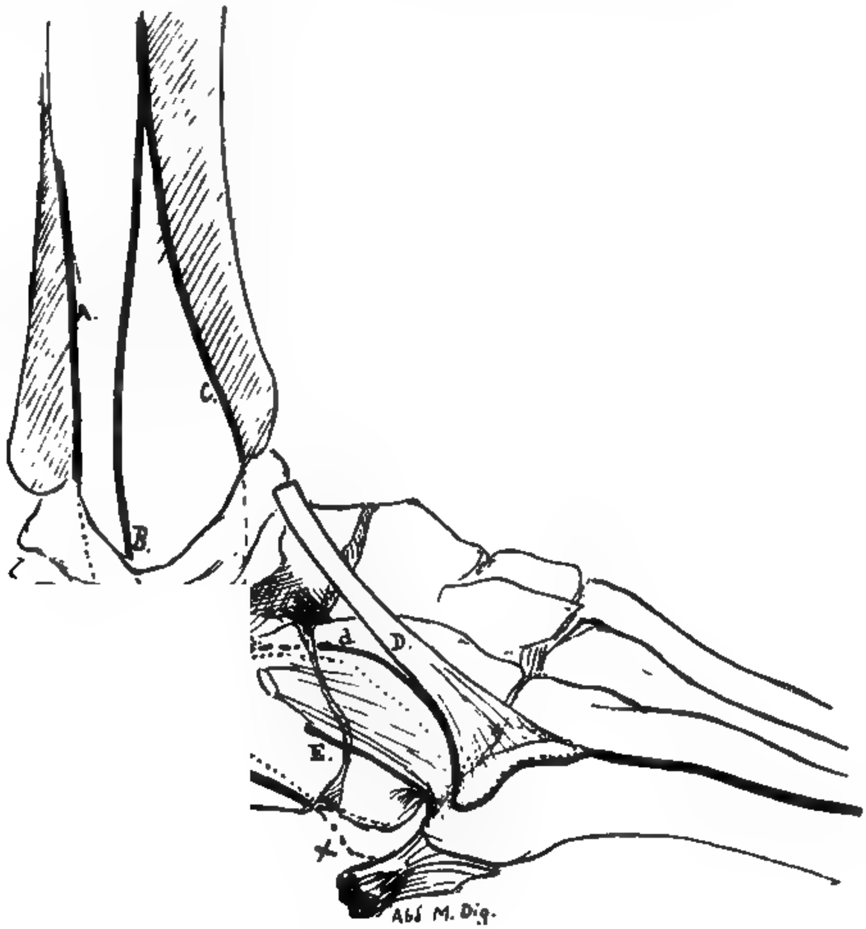


FIG. 11.

divides, giving an appearance as in fig. 9, or in some cases the two lines may separate higher and be more divergent. When there are two lines, the inner septum is pierced by the peroneal artery, as shown in the figure, and there may be a corresponding depression in the line.

Below the fibula the septa cross to the os calcis, generally without attachment to the astragalus.

In fig. 10, seen from the inner side with the ligaments indicated, the line A is that of the annular ligament (transverse fascia) and B that of its inner attachment. The former line runs to the lesser plantar ligament, where the attached structure becomes continuous with the fascia covering the flexor accessorius, and so with the free sheath of the flexor tendons; the posterior marking of this head of the accessorius is usually to be found on the bone, as here the covering membrane is strong, giving origin to fibres of the abductor hallucis, so leading them from the inner tubercle to the annular ligament and even to the scaphoid and inner cuneiform.

The synovial lining of the tendon of flexor longus hallucis does not extend on the bone as far as the fascial covering, but corresponds to the dotted line *a*.

Fig. 11 shows the outer side of the foot without ligaments; line A is that of the posterior peroneal septum, and B that of the anterior. A is some little distance from the synovial reflection (*a*) on the os calcis, and runs down to the calcaneo-cuboid ligaments; X shows the place where the fascial covering attached to A blends with the deep aspect of the plantar fascia and outer structures of the sole.

The line C is that of the outer extensor fascia; at the ankle joint it is incomplete, but below this is continuous through the Y ligament with the fascia covering the short extensor muscle. The attachments of the ligament here need not be described.[1]

The continuation of the line on the tarsus can be taken along the outer margin of the extensory brevis, that is, on the upper part of the outer side of the os calcis in front, in the line *c*, from thence to the cuboid, where (*d*) it curves downwards along the margin of the tendon (D) of the peroneus tertius, blending with this tendon to and round its insertion, and continued in front of it along the upper margin of the outer metatarsal.

Below the fibula the line B is incomplete over the ligament, then runs with the extensor fascia on the os calcis, blending with the tendon of peroneus brevis over the cuboid, so that the synovial sheath of this tendon does not come further than the os calcis.

The short line E marks the position of the septum between the two peroneal tendons; this is apparently formed by synovial reflection usually near its free end, so that there is frequently no corresponding ridge on the os calcis, but where it crosses the cuboid it is a definite and marked septum.

The remaining figures (12, 13, 14, and 15) show the lines on the bones of the left foot.

The outer side of the os calcis shows A, the line of the fascia limiting the

[1] An excellent though incidental account of this ligament is given by Barclay Smith in his account of the astragalo-calcaneo-navicular joint (this Journal, 1894). The superficial limb has a definite marking on the bone, and is the one concerned in the present instance.

outer side of the short extensor, continuous with B, the marking for the ligamentum fundiforme; C is the line of lateral ligamentous fibres, and D that of the posterior peroneal septum; E is the position of the inter-peroneal ridge when present. On the inner side of the os calcis A is the annular ligament and B the posterior attachment of the fascia covering the accessory flexor; C is the line of the inter-flexor septum of the annular ligament, running in front into D, the line of lateral ligament. Posteriorly

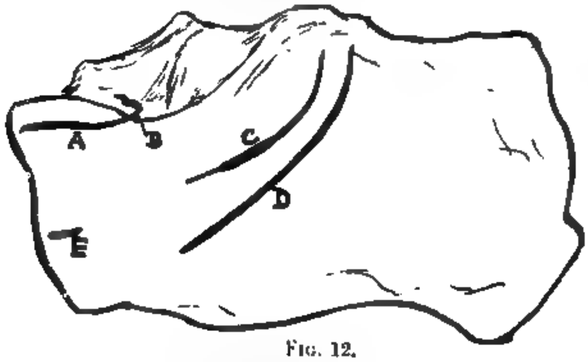


Fig. 12.

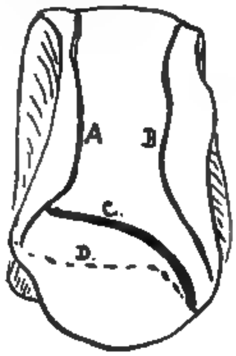


Fig. 13.

Fig. 14.

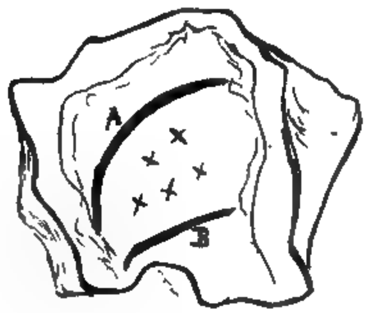


Fig. 15.

no line continuous with C or A is generally found on the astragalus, but D is well represented.

The shaded area is ligamentous.

The scaphoid shows ligament lines A and B, and fascial lines C and D: the last is interrupted, as it may join C further back.

The cuboid, besides ligament lines, has a ridge A for the extensor fascia and B for the inter-peroneal septum: the area X is rough for attachment of fibres of the peroneus brevis.

ON THE PRESENCE OF ELASTIC FIBRES IN THE CORNEA

By J. HAMILTON M'ILROY, M.A., B.Sc., M.B., *Carnegie Research Scholar, Glasgow.* (PLATES XXV., XXVI.)

THE present piece of work was undertaken with the view of demonstrating the development of the cornea in its relation to cutaneous structures, in order that some light might be thrown on the pathology of the corneal tissue.

The subject has been treated from a comparative point of view, and therefore, in addition to the human being, the corneæ of lower animals, when possible, were examined, developmentally and otherwise.

I must gratefully acknowledge my indebtedness to Dr A. Maitland Ramsay for his kind supervision in this work, and for giving me free access to all the material of the pathological laboratory of the Ophthalmic Institution.

The exact condition of matters in the development of the human cornea has always been much disputed. In the lower animals, where the chance of obtaining a continuous series of sections is much more favourable, a great deal of work has been done, and for many species there is a fairly complete description of the development; but in the human species, where the possibility of obtaining examples of all the different stages in early fœtal life is much more scanty, one can understand that great difficulty has been found in making a dogmatic statement as to what actually occurs. In the case of several very young human fœtuses which I obtained for examination, although fixed with all promptitude, yet, when looked at microscopically, they were found to be slightly disorganised and therefore of little use for cellular investigation. In some cases I imagine that the disorganisation was due to the condition which gave rise to abortion, and that the fœtus was born after death had taken place. I had examples of fœtuses from six weeks onwards, with some in the middle term of pregnancy and some in the later months.

Of the examples of the lower animals, those that gave me best results were those of the foal and calf.

DEVELOPMENT OF THE EYE.

The adult cornea consists externally of a layer of epithelium which is a derivative of the epiblast, directly continuous with the conjunctiva,

and somewhat modified for the refraction of light. Little doubt exists as to the origin of this layer; but when it comes to the corneal tissue proper —the substantia propria—we are on disputed ground.

A ring-shaped space is formed between the epithelium and its derived primitive lens follicle, and into this there passes a process of mesoblast. This is at first a structureless layer, and extends right across the front of the lens. According to some authorities, this homogeneous layer is of the nature of an exudation from the corneal epithelium, and therefore epiblastic. It gradually becomes invaded by the corneal corpuscles, which are of connective-tissue origin and are mesoblastic. At the same time a layer of endothelioid cells advances on the inner aspect of this corneal layer, and they constitute the endothelial layer of Descemet's membrane. The cornea grows in thickness through the acquisition of these invading connective-tissue cells, and gradually it becomes more compressed, and changes from a rather loosely knit structure to a finely striated fibrous structure. The compression takes place from behind forwards, so that the posterior layers are more closely packed at first than the anterior. Fig. 14, Pl. XXVI., shows this in a fœtus about the fifth month.

The original homogeneous layer, in front, persists as Bowman's membrane, or "anterior elastic lamina." This is not a proper designation, since the membrane does not stain deeply by stains that pick out elastic tissue. It is thicker at the periphery than centrally, and increases in thickness with advance of life. It is easily seen by the sixth month.

There is a "posterior elastic lamina" or membrane of Descemet which, according to some, is the remnant of the original structureless layer posteriorly; according to others it arises as an exudation from the endothelium covering it posteriorly. It is stained by elastic tissue stains, and decreases in thickness with age. The endothelium covering it is mesoblastic and is continuous with that of the ligamentum pectinatum iridis and the iris.

In early fœtal life there is no aqueous chamber, and the lens remains closely applied to the cornea. It is not till nearly full time that the anterior chamber becomes dilated with fluid (fig. 10, Pl. XXV.)

Analogy of the Cornea in Structure to the Skin.

The analogy of the cornea to the skin, both in development and adult structure, opens up a field whereby the relations of pathological conditions in each might be compared, and it was with this in view that I began my investigation.

The development, structure, and pathology of the skin have received

much attention, and are well established. But I very soon found that, considering the scope of the work, the material I could command for developmental research was too unsatisfactory to be of general use, and I confined my attention in the meantime to the one point of analogy, namely, the presence or absence of elastic fibres in the cornea.

The presence of elastic fibres in the substantia propria has been the subject of much difference of opinion. That they do occur in the human cornea has been affirmed by several, notably Kiribuchi, Prokopenko, and Tartuferi. Their presence has been denied by Stutzer and Sattler.

Kiribuchi showed fine fibrils by the resorcin-fuchsin method, and this was confirmed by Prokopenko by the acid-orcein method. It is generally accepted that they occur in the cornea of the calf. In the skin they occur widely distributed throughout the corium and subcutaneous tissue, in which they form a scaffolding or supporting structure. The fibres may be of a very fine nature, or may be of considerable thickness. In the skin they are said to vary from fibrils of very great delicacy to fibres of 11μ in breadth. They branch and anastomose in an irregular way. They have ends which are clean cut across and often curl up. In the skin their chief function seems to be that of supporting the various structures rather than of giving elasticity.

Elastic fibres resist the action of weak acids, and the other structures do not, so that the fibres are differentiated by prolonged use of weak acids, or it may be a short exposure to the action of strong acids.

With regard to the development of these fibres there has been much dispute. According to some, they are produced by the activity of certain embryonic cells. Others think they are elongated and modified cell-processes. The most likely view seems to be that they arise from growth of nuclei longitudinally. Fig. 11, Pl. XXV., shows the appearance of an elongated nucleus in the midst of young elastic fibres.

Methods of Preparation.

The fixative solution I have found of most value for detail in cell-work is a mixture containing in 100 parts of water 0·25 part chromic acid and 1 part glacial acetic acid. If the eyeball be intact, it is necessary to allow it to remain in this from 10 to 14 days. If the eyeball be divided, 24 hours is a sufficient immersion. It is then necessary to wash in running water for 12-24 hours. After this the tissue is placed in alcohols of constantly increasing strength where it is desired to cut in paraffin or celloidin. But I found that freezing gave least distortion of parts—especially in cases of tangential sections. I consider that while paraffin

and celloidin produce the most picturesque sections, yet one misses much of the natural arrangement of parts, as this may be altered by such histological processes.

For elastic fibres the method of partially macerating the cornea in dilute acetic acid for about three weeks, and making sections by freezing in a tangential direction, was the one that was most satisfactory. Mounting in glycerine was resorted to as a rule in the freezing method, as the treatment necessary to prepare for mounting in Canada balsam also causes shrinkage in the tissues.

FIG. 1.—Human fœtus of about six weeks. Vertical section of the cornea and lens Low power.

a, Corneal epithelium showing loosely scattered cells. *b*, Substantia propria of cornea still homogeneous, but becoming invaded at margins. *c*, Epithelium of lens constriction complete, but lens lies close to cornea. *d*, Posterior segment of lens.

The earliest period of fœtal development of which material for examination in the human fœtus was obtained, was between five and six weeks. (Fig. 1 is from a photograph of vertical section through the front of this eye.) At this stage the cells are still embryonic in character, and have not become differentiated into fibrous tissue, etc. Staining for elastin was entirely negative. The corneal epithelium is seen as a fairly narrow band which passes along in front of the cornea, the nuclei being scattered throughout its extent in a single layer. The lens with its epithelial covering is seen close to the corneal epithelium, but quite distinctly separated from it. The first appearance of the substantia propria of the cornea is seen in the narrow, homogeneous layer which separates the epithelium and the lens.

The connective-tissue cells are beginning to invade it from the side, but as yet have not reached very far towards the centre.

The lens is seen to consist of two segments. The figure gives a fairly clear demonstration of the relation of parts, but the demonstration of minute cellular detail was not possible in the specimen, which, although apparently quite fresh to the naked eye, and fixed with all speed, must have suffered slightly from degeneration.

The next stage at which I examined fœtal material was that of a three to four months fœtus.

FIG. 2.—Cornea of calf. Semi-macerated in dilute acetic acid. Stained by Weigert's method. High power.

Elastic fibres are seen lying in the ground-tissue of the limbus.

FIG. 3.—Cornea of calf. Semi macerated in acetic acid. Highly magnified.

The specimen is taken from the limbus. Tangential section. Weigert's stain. The elastic fibres are distinct, especially towards upper part of figure. The large black masses are the pigment cells of the ciliary body, and locate the site which is at the limbus in its deeper layers.

When I began my investigation, I did not realise that it was not possible to obtain a good demonstration of the presence of elastic fibres from the ordinary vertical sections of the cornea. It was only when I began to macerate slightly in acetic acid, and make frozen sections in a tangential direction, that I could obtain a view of the fibres to my satisfaction. In a lamellar structure such as the cornea, when the fibres are compressed between the lamellæ, they may readily escape notice, especially if the differentiating process, after staining, is not completely carried out. This is only one illustration of how the component parts of a section may be missed, especially in one which has undergone shrinkage from any cause, such as is met with in the paraffin or celloidin methods.

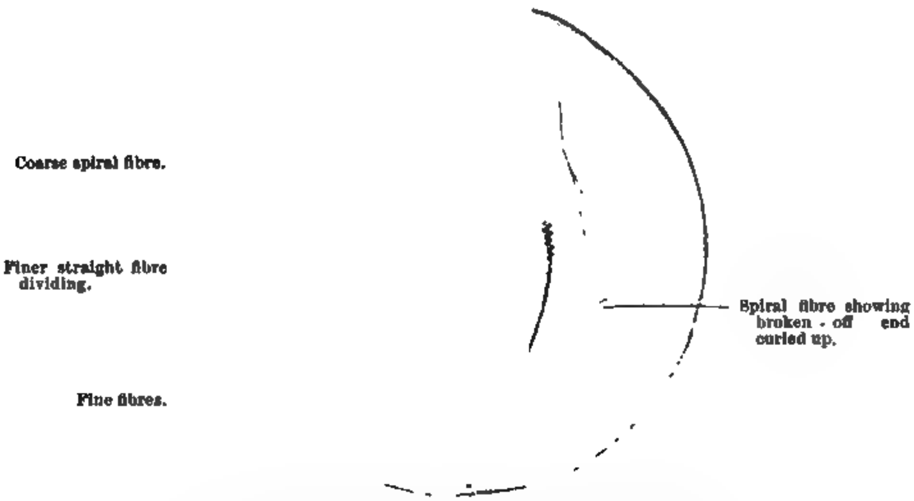


FIG. 4.—Piece of macerated cornea from the calf.

Piece of cornea which had been macerated for four to six weeks in dilute acetic acid, teased out on slide, and then stained by Weigert's stain.

Some of the elastic fibres are distinctly wavy in outline and of considerable magnitude; others are quite straight for a considerable part of their length. Fine fibrils pass from one fibre to another at places.

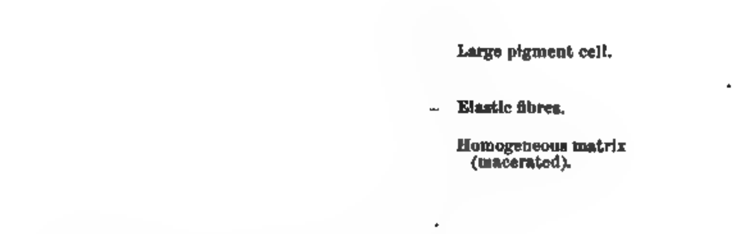


FIG. 5.—Cornea of young calf. Semi-macerated in acetic acid. Tangential section.

Cornea at limbus.—Frozen tangential section stained by Weigert's elastic method.

Fine fibrillar network of elastic fibres. The homogeneous matrix represents the disintegrated tissue which constitutes the rest of the cornea at this part.

As early as the third or fourth month the fibrous nature of the human cornea is well established. Here and there amidst the wavy fibrous tissue one can make out the sharply cut end of a more deeply stained fibre. The posterior layers are more compressed than the anterior, and it is at this region that the cornea takes up the elastic stain more or less uniformly.

At the third month Bowman's membrane is not seen as in the adult cornea, but is represented by a matrix with some more or less loosely scattered corpuscles lying in its substance. Fig. 16, Pl. XXVI., shows a specimen of this age in which the cornea is stained by Weigert's elastic

FIG. 6.—Cornea of calf. Semi-macerated in acetic acid. Tangential view. Weigert's stain.

Coarse, spirally twisted fibres can be seen lying in homogeneous matrix at limbus. The pigment corpuscles indicate that the region is the deeper zone over the ciliary area.

stain. The difficulty of differentiating elastic from other tissue is shown in this specimen.

It is stated as a fact beyond dispute, that elastic fibres occur in the cornea of the *calf*. I therefore took this as a basis of comparison, and used it as a method of control for the other material examined. In all my preparations I found a freshly prepared Weigert's elastic stain was the most satisfactory, although in some cases I got quite good results from the orcein method. Figs. 2 and 3 show the presence of elastic fibres in the calf's cornea. The preparations were macerated for three to four weeks in dilute acetic acid. By this treatment the cornea became swelled and the cells somewhat indistinct in outline. Frozen sections were prepared, or portions of the cornea at the various parts were excised and pressed out

between cover-glass and slide. In this latter way a film preparation was produced, and this was stained as mentioned in the description appended to the figures.

In the superficial layers (see fig. 4) which comprise the loose areolar tissue just beneath the conjunctiva outside the limbus, elastic fibres are very abundant. In this region they are broad and wavy, and form a more or less thick feltwork. In the deeper layers (fig. 5) and more internal to the limbus, the fibres are somewhat finer and more delicate.

FIG 7.—Human fœtus about eighth month. Limbus corneæ. Semi-macerated in acetic acid. Tangential section.

The very long, fine elastic fibres are in some places slightly waved, in others almost straight. The fibrous background seen in the right-hand corner is the sclerotic tissue. The corneal tissue lies on the opposite side.

They are more isolated, and the anastomosis with one another is more obvious. The fibres become more scanty towards the centre of the cornea, and in the most central part they are absent altogether. The large pigmented masses which appear in some of the sections are the pigmentary cells of the ciliary process, and are seen in those sections which have passed through the deeper layers of the limbus.

We therefore see that the elastic fibres are found chiefly in the deeper layers of the cornea, near Descemet's membrane, and are confined to the peripheral portion of the cornea.

In the human cornea the condition is found to be practically the same. The specimens which showed the presence of the fibres most clearly were

those of the later months of pregnancy. In fig. 12, Pl. XXV., the limbus area in a tangential section is seen under a low power of magnification. The stain was Weigert's resorcin-fuchsin. The densely fibrous nature of the sclerotic merging into the somewhat hyaline (when macerated) region of the cornea through the limbus is indicated. In fig. 7 the same appears under high magnification. The fibres are seen passing across the limbus into the peripheral part of the cornea. In this region they are of an extremely fine and delicate nature even when highly magnified. This

FIG. 8.—The cornea of foal. Tangential section. Superficial layers. Semi-macerated in acetic acid. Low power view Weigert's stain. Taken from region of limbus.

Note.—The dense mass of elastic fibres at lower part of diagram. The fibres are very coarse in character.

FIG. 9.—Cornea of foal. Semi-macerated in acetic acid. At limbus.

Showing fine network of elastic fibres under moderately high power of magnification. The section is tangential and frozen. The dark areas at lower part are the pigment cells of the ciliary body.

specimen is from a fœtus about the seventh or eighth month of pregnancy. Fig. 7 is from a photograph of superficial layers at the limbus. In this specimen long, isolated fibres are found in abundance in the superficial layers just beneath the conjunctiva at the limbus, but these are lost when the epithelium becomes definitely corneal in character. Fig. 13, Pl. XXV., shows the condition of matters in the vertical section of the same specimen.

The difficulty of demonstrating the elastic fibres is apparent here. Whereas they do not appear in the midst of closely packed lamellæ, yet they are readily seen in the loose conjunctival region just beyond the limbus, even under a low power of magnification.

In the more advanced specimens, and in adult corneæ, fibres can be shown to exist at the limbus, in the deeper layers.

Beginning of anterior chamber

Lens.

Posterior zone of lens Chorioid.

Section of eyelid showing glands, etc.
Cornea showing denser posterior part.

Ciliary process.

Epithelium covering lens.

Retina.

FIG. 10.—Human fœtus. About fourth month. Section of front of eye *in situ*.

FIG. 11.—Elastic fibres. Fœtus about eighth month.

Cornea showing homogeneous structure.

Sclerotic showing fibrous structure.

Substantia propria of cornea.

FIG. 12.—Human fœtus. Celloidin. Weigert stain. Tangential section. Low power. Obj. 3. Oc. 3. Leitz.

Limbus corneæ.

Fine elastic fibre For clearness it is represented too large for scale of diagram.
Sclerotic.

Ciliary processes.

FIG. 13.—Human fœtus. About eighth month. Semi-diagrammatic. Vertical section.

MISS J. HAMILTON M'ILROY.

Anterior less dense portion where corpuscles have not yet undergone compression.

Posterior (… thelial) layer

Anterior corneal epithelium

Corneal corpuscle seen lengthwise.

Corneal corpuscle seen cut across.

Posterior p… where corp… are closely p… and a dist… laminated ap… ance is prese…

Region of Bowman's membrane.

FIG. 14.—Human fœtus. About fifth month. Cornea near the middle. Vertical section.

FIG. 15.—Foal's cornea. Frozen tangential section. Middle zone. Weigert stain. Oil immersion $\frac{1}{12}$. Leitz. Oc. 3.

Descemet's membrane and epithelioid layer.

Embryonic corpuscle.

Region which will become Bowman's membrane.

Denser band of fibres posteriorly

Corneal surface.

Less dense part.

Corneal epithelium

FIG. 16.—Human fœtus. Three to four months. Weigert stain.

Sclerotic surface.

FIG. 17.—Human fœtus. Celloidin. Weigert stain. Tangential section. Oil immersion $\frac{1}{12}$. Oc. 3. Leitz. Semi-diagrammatic. Limbus corneæ. Showing elastic fibres.

Similar results were obtained in the cornea of the foal which I have examined. Figs. 8 and 9 show the presence of elastic fibres in great abundance. In fig. 8 the coarse, wavy fibres occupy the superficial layers just under the conjunctiva, and illustrate the felt-work condition referred to already. In fig. 9 the fibres exhibited are in the deeper layers and are more delicate in character.

Conclusion.

Although denied by many authors, I have proved to my satisfaction that elastic fibres occur in the cornea. They are chiefly restricted to a zone round the periphery of the cornea, and become lost to view as the central part of the cornea is reached. They are demonstrable in almost equal distinctness, by the Weigert method, in the eye of the human being, in that of the calf, and young horse. In the early weeks of human fœtal life the tissues are still embryonic, and do not take up elastic staining. Definite fibres appear about the third or fourth month. The fibres in the cornea proper are perhaps more abundant in the middle term of pregnancy, but can be demonstrated at the limbus in the later months of extra-uterine life, and in early adolescence.

Preparations, to be satisfactory, must be sections made in a tangential direction, and should be stained by the resorcin-fuchsin method of Weigert.

I have to point out that in a piece of work of this kind it is difficult to obtain good illustrations. I had to make repeated attempts, as the stains do not lend themselves readily to photographic reproduction.

The distinctness of outline necessary for illustration in this way is absent from these semi-macerated specimens, and the elastic fibres are not sufficiently obvious in many instances to make them stand out clearly against the background.

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SIXTEENTH REPORT ON RECENT TERATOLOGICAL LITERATURE. By BERTRAM C. A. WINDLE, M.D., Sc.D., F.R.S., *President of Queen's College, Cork.*

[The author of this report will feel greatly obliged if writers on teratological subjects will supply him with reprints of their papers for use in the preparation of future reports.]

I. EXPERIMENTAL.

TUR (i.) has incubated some "*first-laid*" *eggs*, it being well known that such eggs seldom produce normal chicks. The eggs were incubated up to different stages, then fixed, stained, and examined. He describes five blastoderms. (1) 16 hours. Short, broad, primitive groove at the hinder extremity of the area pellucida. At the anterior end of this groove a small deep transverse groove. This was a gastrula-like inflection of the kind typical in reptilian embryos. (2) 23 hours. Primitive groove, at anterior end of which is a compact, transversely lying thickening with an irregularly bent deep transverse cleft, which the author considers to be a prostoma. (3) 26 hours. In the middle of the area pellucida is a complex malformation, an irregular anterior spot, a strong oval thickening, and behind a vesicular kind of formation. (4) 13 hours. Primitive groove with anterior deep transverse fissure visible. This is shown by microscopic sections to be a sinking-in of the ectoderm, apparently an early stage in the formation of a prostoma-like gastrulation. (5) 15 hours. At the anterior end of the primitive groove is a small thickening. At the hinder end also a compact thickening with a deep cleft. In this case examination showed that there was no gastrulation, but a very extreme amount of ectodermal growth.

II. GENERAL.

CALWELL (ii.) describes two cases of *dwarfism*. The first is one of infantilism, primary asexual ateleiosis; the other, a female, was sexual, and the diminutive stature was due to excessive scoliosis, with bent lower extremities. LAUNOIS and ROY (iii.) have published an important work on *Giants*, which may be mentioned for the sake of those working at this subject. It may be remarked that the authors state that hypertrophy of the pituitary body and disproportionate enlargement of the sella turcica are scarcely ever absent in giants, and especially in their second group, acromegalic giants. REGNAULT (iv.) notes that *achondroplasia* gives rise to deformities due to the want of resisting power in the bones, so that the pelvis is deformed, the neck of the femur is shortened and makes almost a right angle with the body, the head of the femur is crushed and flattened, and the articular surfaces of the knee and ankle also appear to be crushed. To these appearances he adds another, namely, platybasy, or flattening of the base of the skull around the foramen magnum, due to the pressure of the vertebral column on an occipital bone with insufficient resisting power. A series of papers have appeared on *achondroplasic*

cattle. These may here be grouped together. REGNAULT (v.) declares that all authors have confounded achondroplasic and niata cattle, which are really two distinct types. Niata cattle form numerous herds in Chili, and are met with occasionally in Europe. Such an animal is characterised by a short face, shortened and widened superior maxillæ and intermaxilla; similarly constituted nasals and lachrymals, the last, losing its normal relations with the cranial bones, is interposed between the frontal and intermaxillary: the palate bone is little modified. As a consequence the palatine vault is widened, shortened and convex from before backwards. The facial profile is convex. The mandible curves itself and forms an arch which is very strongly curved inferiorly in order to preserve its relations with the maxilla. The base of the skull is unaltered. The achondroplasic calf is characterised by an arrest of development of the bones of the base of the skull, so that the forehead swells out under the pressure of the brain. The maxillæ, hindered in their development above, develop mesially and inferiorly. Hence results a concave profile with its angle at the root of the nose. The mandible is even more fully curved than in the niata. The limbs in the niata are short but well developed, which is not the case in the achondroplasic. Arrest of development in the niata is limited to the maxillary region. SELIGMANN (vi.) describes the "bull-dog calves" which are met with, it appears, in this country only amongst the pure Dexter-Kerry breed, and perhaps very rarely amongst half-bred Dexters. The condition is described by him as one of congenital cretinism. Such cretins show the characteristic gross lesions and histological changes in a marked degree, including those first described by Edmunds in the thyroid of human cretins. The condition cannot be ascribed to inbreeding, but clinically is constantly associated with placental disease in the parent cow; and when it has been possible to examine the placentæ from cretin births, marked and constant changes have been found. No satisfactory explanation can at present be given of the occurrence of cretinism in the Dexter breed only. As for its association with a constant form of placental disease, the latter may be considered as an indirect or secondary factor in its production, by preventing the access of the maternal thyroid secretion to the fœtus in which the thyroid lesion characteristic of cretinism has arisen. LESBRE and FORGEOT (vii.) deal with the same "bull-dog calves," and allude to Seligmann's paper. According to these writers, thyroid dystrophy is not the determining cause of achondroplasia, it is only a complication of it. They think that the cause is an "intoxication infectieuse," and suggest that what is wanted is that the nature, origin, and conditions of this intoxication should be investigated. LESBRE and FORGEOT (viii.) describe another achondroplasic calf which was born dead in an extraordinarily anasarcous condition. Dissection showed that both kidneys were absent. BAYON has published a series of notes on cretinism and allied conditions. In one (ix.) he deals with the microscopic anatomy of the hypophysis, epiphysis, and peripheral nerves in cretinism, and describes the deviations from the normal met with in these portions of the body. In another (x.) he describes the condition of the thyroid body in cretinism and myxœdema. A third (xi.) deals with the same subject, and a fourth (xii.) with supposed early synostosis amongst cretins and the supposed relationship between chondrodystrophia fœtalis and athyreosis. In this he states that early synostosis is never found in true cretins, that the opposite view is due to a confusion of cretinism with chondrodystrophia fœtalis hypoplastica, in which again no early synostosis is met with, but only a stoppage of enchondral growth. The two diseases just mentioned have no pathological identity with one another, and etiologically no point of contact between the two

diseases has been recognised. RABAUD (xiii.) critically examines the question of the *rôle of the amnion in the production of malformations*, a question so long debated. He denies that the results of compression, constriction, or adhesion are really teratological, though they are congenital, the action of the amnion in these directions being only that of modifying some normal structure, "Jamais il ne modifies ni le sens des différéntiations, ni la marche de la croissance." The following have dealt with *transposition of the viscera*:—HALFF (xiv.), stomach, duodenum, and spleen transposed in a male. M'CRAE (xv.) two cases, in one of which there was also atresia of the pulmonary artery. M'CRAE (xvi.) a further case.

The following are cases of *hermaphroditism*. JARRICOT (xvii.), aged 64, supposed to have been a female all life. Autopsy showed that the individual was a male. The penis was rudimentary and there was no corpus spongiosum. There was perineo-scrotal hypospadias. MONCANY and DELAUNAY (xviii.), child, lived four days. Penis reduced to a glans about 1 cm. in length with a gutter on its inferior surface. Urethra opened between two pseudo-labia majora. No vagina. Testicles placed on each side of the rectum at the level of the internal ring. Here again there was no corpus spongiosum. BATUJEW (xix.), new-born child. Internal organs entirely female; external, male with hypospadias. JONES (xx.), gynandroid monster of seventh month; had also hare-lip, cleft palate, absence of right palpebral fissure, its place being occupied by the orbito-nasal groove. CORBY (xxi.), patient, aged 15, had been considered a boy. Cretinoid, six toes each foot, and a sixth finger had been removed. External genitalia like those of a female, but with what looked like a non-developed penis protruding from between the labia majora. He was the eighth child, and the fourth (dead) had been exactly like this one. Patient was operated upon for a tumour, which turned out to be ovarian, but was placed or had originated in the inguinal canal. At the time of the operation a uterus was discovered. SHATTOCK and SELIGMANN (xxii.), true hermaphroditism in a fowl. The bird in question was a two-year-old Leghorn fowl, which externally exhibited the comb and wattles, with the spurs of a cock, but the tail of a hen. Its sexual physiology was quite negative. The dissection showed a well-developed left oviduct, and a short diminutive right; a vas deferens was present on each side. The sexual glands were convoluted on the surface, and of altogether abnormal form. The left gland consisted of inactive tubuli; serial sections of its lower end revealed two ova, each provided with a follicular wall; the vitellus of each presented an eccentric oval space answering to a germinal vesicle. The serial sections proved the structures in question to be spherical and not cross-sections of distended tubes, none of which were anywhere present. The sexual gland of the right side was the smaller, and consisted of inactive tubuli like the left, but at one spot a group of tubuli was met with in which active cell proliferation and spermatogenesis were in progress. Each gland was furnished with a vas deferens, and the oviduct of the left side was fully developed, the sexual gland of this side being that which contained the ova. Potentially, therefore, the bird was capable of performing to the full extent both male and female functions. The authors had been led from this specimen and other data to hold that the not uncommon change of plumage from female to male, and more rarely from male to female, possibly indicated a bisexual character. FANTHAM (xxiii.), cases occurring in testudo græca. (A) a bilateral hermaphrodite according to Taruffi's classification; (B) functionally a male, though with female characteristics, and might be regarded as a pseudo-hermaphrodite. MEYER (xxiv.) describes some *abnormalities at the tail-end of an embryo*. There was doubling of the spinal canal, with remains of the notochord, caudal spinal canal, neurenteric canal, and post-anal

gut. WINSLOW (xxv.), *abnormalities in urodeles.* (1) Amblystoma punctatum with a bifid toe; (2) another with five legs; (3) plethodon glutinosum with a bifid tail. FRIEDHEIM (xxvi.) gives a series of cases of malformed fœtuses, including several of *spina bifida*, cyclops, encephalocele, etc. JACOB and FULTON (xxvii.) describe a family in which *keratosis* palmaris et plantaris had existed for five generations.

DOUBLE-FORMATIONS.

- **SYMMETRICAL.**
  - I. Complete doubling. (Two separated bodies.) Duplicitas completa.
    - *a.* Equal.
    - *b.* Unequal. (Autosite—parasite, Parasitus truncatus.)
  - II. Incomplete doubling. (Partly doubled bodies.) Duplicitas incompleta.
    - *a.* Equal.
      - 1. Conjunctio inferior.
        - Union extending from below upwards.
          - Union confined to lower part of body.
            - (α) Dorsal. Pygopagus.
            - (β) Ventral. Ischiopagus.
          - (γ) Ischio-ileo-thoracopagus. (So-called dicephalus.)
      - 2. Conjunctio media. (Duplicitas parallela.)
        - Union from umbilicus outwards.
          - (α) Xiphopagus.
          - (β) Sterno - thoracopagus. (Rachipagus - thoracopagus parasiticus, dicephalus.)
          - (γ) Gastrothoracopagus dipygus. (Heteradelphus.)
          - (δ) Prosopothoracopagus.
      - 3. Conjunctio superior.
        - Union from head backwards.
          - (α) Dorsal: Craniopagus (epicomus). — frontalis. / parietalis. / occipitalis.
          - (β) Ventral ventro-lateral. Syncephalus. (Cephalothoracopagus janiceps.) Janus.
            - Symmetros.
            - Asymmetros.
    - *b.* Unequal.
      - 1. Upper (ant.) doubling. (Duplicitas superior.) Diprosopus. (Cyclops.) Dicephalus sensu stricto (?).
      - 2. Lower (post.) doubling. (Duplicitas inferior.) Dipygus.
  - III. Triple forms. (Mostly combinations of I. and II.)
- **ASYMMETRICAL.**
  - (True parasites.) Inclusio fœtalis. Fœtus in fœtu.
  - 1. At head-end of autosite.
    - *a.* Prosopopagus parasiticus.
    - *b.* Epignathus. (Spheno - uropagus.)
    - *c.* Encranius.
    - *d.* Cephalomelus. (Of doubtful occurrence in man.)
  - 2. In the region of the branchial arches or mediastinum.
  - 3. Thoracomelus, notomelus. (Of doubtful occurrence in man.)
  - 4. In the anal region. Sacral parasite. (Teratoma sacralis, Pygomelus.)
  - 5. Between the abdominal walls. (Inclusio subcutanea.)
  - 6. In the abdominal cavity. (Intraperitoneal, mesenterial.) Engastrius.
  - Dermoid cysts.
  - Teratomata.

III. Duplicity.

Bernheim (xxviii.) has described another case of *quintuplets*. The mother was aged 39, was married at 17, and had borne 7 children. All of the five at this birth were males. The five placentæ were fused, but there was apparently a separate chorion for each child. One survived for a fortnight, the rest died before that time. The weights in order of birth were 4, 4¼, 4¼, 4¼, 5 pounds.

Roberts (xxix.), a case of several multiple births in same female. She was aged 32, of French extraction, married twelve years. There was a history of twinning on her maternal side, and her own six confinements had been (1) twins, (2) triplets, (3) a single child, (4) twins, (5 and 6) single children. Besides there had been a miscarriage with a single fœtus. On this occasion she produced four children—boy, boy, boy, girl. There were four separate placentæ and four bags of membranes. The third boy was still-born, but all the others survived at the time the communication was made.

Féré (xxx.) describes a pair of twins, not closely resembling one another, who, when 13 years and 6 days old, were simultaneously attacked with pains in the head and other symptoms, and two days after began to menstruate at the same time. This additional instance of the close relationship in constitution of twins seems worth recording.

Strassmann (xxxi.), in a paper on *twins and double-formations*, gives in a tabular form a classification, based on Marchand's views, which is so useful that I reproduce it for the benefit of English workers.

The systematic account of *multiple formations in man* from the pen of Strassmann (xxxii.) in v. Winckel's Handbuch, may be commended to English teratologists as an excellent account of the subject with which it treats. Förster (xxxiii.) thus sums up his views as to the *origin of double malformations*. Observations on artificial disturbance of embyronic development show that the view that asymmetrical double malformations may be formed in the unfertilised ovum is untenable. Experiments do not prove that double malformations may come from eggs with two germinal vesicles. Experimental observations exclude polyspermia as a cause of duplicity. All observations seem to show that symmetrical double forms can be produced by alterations in the fertilised ovum. This alteration may perhaps be a complete separation of the first fission spheres. Far more probably, however, it is a rearrangement of the cell material either during fission or in the blastula or gastrula stage which produces a duplication. Separation of the first fission spheres or rearrangement of the cell material may most probably be produced by a change in the osmotic pressure in the ovum, perhaps also by mechanical influences on the ovum. Alexander (xxxiv.) deals with the condition of the internal ear in *syncephalus* (synotia). He says that the processes have their commencement evidently in a very early embryonic stage, and that they affect the seventh and eighth nerves, the ganglion acustico-faciale, the capsule of the labyrinth, and the membranous labyrinth as well, and that even those parts of the labyrinth which are not directly affected are retarded in development as compared with the condition in a normal embryo. Tur (xxxv.) has a paper on *multiple embryos*. Amongst numerous bird embryos which he examined, he found several multiple developments in the stage of the primitive streak and the primitive groove. He describes one remarkable case observed in the egg of a hen. There were four separate centres of development. On three of these there was a primitive

groove, and one of these grooves was double. In another paper (xxxvi.) the same writer gives three *rare cases of duplicity in the hen*, all very early in stage. (1) Two symmetrically bent primitive streaks in one area pellucida. These streaks were so arranged as to form an X-shaped figure. (2) A very similar and also X-shaped case. In both these cases the head-ends were turned in one direction and the tail-ends in the opposite. (3) Also two primitive streaks but of different size. These had their head-ends turned towards one another. The same writer (xxxvii.) describes a very *early double malformation of lacerta oculata* consisting of two primitive streaks lying parallel with one another. CHIARI (xxxviii.), a *thoracopagus* found as the result of a three months' pregnancy. The head and buttocks measurement of each embryo was 14 mm., *i.e.* about six weeks, but the size of the membranous sac would point to three months' development. ANTHONY and SALMON (xxxix.) contradict the view that *pygomelus* is a parasitic form or asymmetrical, believing that it is a symmetrical form of double monstrosity. They have established a series of double monsters formed by union face to face of two individuals (syncephalus) showing a passage by insensible transitions between janiceps, in which the union takes place only at the level of the cephalic region and pygomeles, where the union, instead of stopping at the head, at the neck, or at the thorax, goes as far as the pelvis. The two coccyges approximate towards the middle line, the posterior members approach one another, meet, and, in certain cases, unite with one another, all being cases of pygomelus of different degrees. RABAUD (xl.), an account of a case of *monocephalus deradelphus* in a cat, with full description of the anatomy. The author maintains that the medullary axes never were the axes of two separate independent forms, but that the two limit a region in which organs are formed simple, double, or duplex as the case may be. The simplicity, duplicity, or duality of the heart, for example, depends entirely on the amount of the extent of the region of common development. OPEL (xli.), a case of *pygomelus* (heterodidymus triscelus of Gurlt), where there was also spina bifida and duplicity of the bladder. Case of *acephalus*, GOWDEY (xlii.), both upper limbs present; female in sex like the normal child with which it was born. Weighed 3 lbs. 3 ozs.; absolutely devoid of even a rudimentary head. Forearm absent in right upper limb, the hand, with only three digits, being in contact with the lower end of the humerus. The left upper limb consisted of a very short humerus, a forearm, and hand with five digits. There were five toes, all webbed, on the right foot, three only on the left. A further case has been described by GLADSTONE (xlii.), DUCLAIX and HERRENSCHMIDT (xliv.), *teratoma of the labium majus*. Tumour, which was congenital, was of the size of a goose-egg, and occupied the right labium majus. It had two mamillary elevations on it and an anus-like opening which led into an oblique diverticulum. Vagina and uterus were both double. The tumour was removed and microscopically seemed to be composed of fat. Microscopic examination of the mucous membrane of the diverticulum showed that it was of a character similar to that of the anus, and the authors think that the case is one of a fœtal inclusion of one or several parts of the posterior intestine (not caudal) in the neighbouring tissues, an inclusion which may perhaps have been produced by an irregular formation of the cloaca. These fragments, they think, may have developed into the ano-rectal passage open to the exterior (*i.e.* the diverticulum described), and into a cyst which also existed in the substance of the tumour.

IV. Head and Neck.

Cases of *absence of corpus callosum*, Banchi (xlv.). This appears to be a fuller description of the case mentioned in the last of these reports. The author says that he cannot give any clue to the etiology, but thinks that the suggestions put forward by some as to the action of a hydrocephalous condition or of a meningeal obstruction are quite inadequate. Douglas-Crawford (xlvi.), another case. He thinks it demonstrates that the fornix commissure appears before the callosal, and that the dorsal portion of the corpus callosum is the first part of that commissure to appear in the commissure field immediately anterior to the fornix. Haushalter and Collin (xlvii.), another case, with microgyria and polygyria, also absence of the pyramidal tract. Bourneville and Raymond (xlviii.), *porencephaly* of both hemispheres. Left side, occupies the greater part of the temporal lobe, same position in left; sclerosis of external portion of the cyst less marked on this side. The case occurred in a child of four years of age, idiotic from birth. The condition of the *circle of Willis* and its abnormalities has been investigated by Longo (xlix.), and Fawcett and Blachford (l.), Piel (li.), *congenital malformations of the ear*. (1) In cases of congenital atrophy of the external ear arrest of development is not localised in the soft parts, but extends also to the deeper, affecting the neighbouring bones, temporal, maxillary, and frontal; (2) the abnormalities are not confined to the region of the first branchial cleft, but occupy one or more metameric segments.

Congenital *absence of the dilatator of the pupil* has been described by Grossmann (lii.) in a girl of 5½ years. *Abnormalities of bones of the skull.* Frassetto (liii.) figures six monkey and six human crania to show that the parietal may be divided into two halves by a vertical or by an antero-posterior suture, and that one of these may again be divided into two. Hence the parietal may consist of three parts. As the secondary suture may sometimes be in the anterior and sometimes in the posterior portion, the parietal might consist of four parts, and this condition the author has actually demonstrated in the skull of a Cercopithecus callitrichus. Hrdlicka (liv.), cases of division of the parietal in man and monkeys. Bradley (lv.), supernumerary ossicles in the skull of a lion. (1) The left lachrymal has a triangular ossicle separated from it which lies between the main portion of the bone, the frontal and the maxilla; (2) right nasal divided into two unequal portions by a longitudinal suture which leaves the internasal suture about the junction of its middle and anterior thirds. Hrdlicka (lvi.), two cases of bilateral complete division of the malar in man. Bradley (lvii.), a case of *supernumerary molar teeth* in the horse, with a discussion on the subject of variation in the number and form of the premolars and molars in the horse. Bradley (lviii.), a *supernumerary first maxillary premolar* in the horse. Lucas (lix.) recalls a former paper on congenital *absence of an upper lateral incisor tooth* as a forerunner of hare-lip and cleft palate. (*Clin. Soc. Trans.*, 1888, p. 64), in which he stated that the absence of an upper lateral incisor tooth resulting from an arrest of development is to be regarded as a malformation closely related to hare-lip and cleft palate and capable of transmitting both of these deformities to a succeeding generation, and now gives two further cases illustrative of this theory. Debasieux (lx.), *median hare-lip, etc.* Child aged 2 months. The upper lip is divided at its centre by a vertical fissure which commences at the free border and occupies about two-thirds of the lip. This fissure is continued by a groove which extends to the root of the nose. The nose itself is

divided into two parts, each consisting of a single nostril, separated by some distance from one another. There was also a median cleft of the palate affecting the alveolar portion only. The sides of the cleft were nearly in apposition. HENTZE (lxi.), an inquiry into *hare-lip and cleft palate*, mainly in connection with the question of treatment. PETIT (lxii.) describes a *cervical cyst* occurring in a dog. It was about the size of an egg, and lay against the right side of the larynx; was lined with polymorphic epithelium and had a fibro-vascular covering. He believes that it was of branchial origin. KREBS (lxiii.), *congenital cartilaginous remains in the neck.* He holds that they are only found as remains of the second branchial arch, and that chondromata of the salivary glands are not referable to the same cause. BATUJEW (lxiv.), two punctiform openings in the neck of a man aged 21, believed to be *incomplete branchial fistulæ.*

V. THORAX.

EHRHARDT (lxv.), *Sprengel's deformity.* First described in 1891, this condition of elevation of one shoulder above the other has now been recorded in 89 instances. The author now adds three fresh cases, and gives a full bibliography and analysis of the cases on record. KEITH (lxvi.) has a valuable statistical inquiry into cases of *congenital cardiac* malformation, to which workers on this subject may be referred for a number of significant facts.

LAUNOIS and VILLARET (lxvii.), *abnormalities of the sigmoid valves of the heart.* The most frequent anomaly is the absence of a valve. It is rare to find one supplementary valve, still rarer to find two. There is only one case of a single aortic valve. It is very rare to find simultaneous anomalies in the two great arteries. The abnormality is clearly congenital.

VI. ABDOMEN.

GARROD and WYNNE-DAVIES (lxviii.) *absence of the muscles of the abdominal wall,* with hypertrophy and dilatation of the urinary bladder, linear scarlike umbilicus, and undescended testicles. No intra-uterine poliomyelitis. Stumm put forward three views as to causation, viz., (1) that the condition of the bladder was due to the non-development or atrophy of the muscles, (2) that the two malformations had a common cause, (3) that the non-development or atrophy of the muscles was secondary to a temporary obstruction of the escape of the urine occurring during intra-uterine life. The authors think the third theory is likely to be the correct one. ROSENHAUPT (lxix.), a case of *abdomino-pelvic fissure* with division of the intestine, absence of the right umbilical artery, and double uterus.

Cases of *diaphragmatic hernia.* MURRAY (lxx.), girl, aged 4 months. The hernia was on the right side and contained the large intestine, most of the small, the gall-bladder, and parts of the liver and pancreas. RABAUD (lxxi.), case associated with a remarkable short œsophagus which the author thinks may have been the prime cause of the defect. PETIT (lxxii.), case occurred in a cat and was on the left side. The stomach, spleen, small intestine, pancreas, and great omentum were all in the pleural cavity. He mentions that he had previously described a case of the same kind in a dog. BROOK (lxxiii.), a case of congenital *dilatation and hypertrophy of the sigmoid flexure* in a female aged 21. *Abnormalities of kidney.* HORAND (lxiv.), right kidney absent and right ureter connected with the left

kidney, a very remarkable case. Dick (lxxv.), single fused kidney in a fœtus, also the subject of uterus duplex. Niclot and Heuyer (lxxvi.), pelvic ectopia of both kidneys in a male. Both lay in the pelvis below the level of the bifurcation of the aorta, the right being lower than the left. Both were turned round so that the posterior aspect was anterior. The right received its arteries from the right common iliac artery, and the left from the aorta just above the point of bifurcation of that vessel Romanovsky and Winiwarter (lxxvii.), *ectopia testis* in a male aged 61. The right testis lay with the left in a common tunica vaginalis in the left sac of the scrotum, both spermatic cords passing through the left inguinal canal. Guizzetti (lxxviii.), a case of *absence of vas deferens and vesicula seminalis* on the right side. The corresponding testis was well formed and the spermatozoa were normally developed. Dieulafé and Gilles (lxxix.), child with atresia ani, operated on and died the second day after birth. Had an *enormous penis*, measuring 7 cm. in length. The orifice of the meatus was filiform. Behind this the spongy portion of the urethra presented a number of much dilated cavities separated by narrowed portions of the passage. De Blasio (lxxx.), a female presenting *supernumerary mammæ*, one on the exterior of either labium majus. Cases of *uterine abnormalities*. Lane (lxxxi.), septate uterus and vagina. Alglave (lxxxii.), patient aged 40. Uterus much bent to left side and united to pelvic wall,—a congenital, not a pathological condition. The portion in question represents the left side of the uterus only, the right Mullerian duct forming only a rudimentary tube. The corresponding (right) ovary lay in the iliac fossa behind the cæcum, and resting by its lower pole against the external iliac artery. The right kidney lay in the pelvis, its superior pole between the two venæ cavæ inferiores. Complete *atresia vaginæ*, described by Batzewitsch (lxxxiii.), and believed by him to be congenital, though this was denied by others. Large fold of skin over posterior fourchette described by Jones (lxxxiv.).

VII. Extremities.

Veit (lxxxv.) discusses the question as to whether there is any connection between *polydactyly* and cerebral malformations. He considers that sporadic and unilateral examples of polydactyly may be due to mechanical processes, but that hereditary and symmetrical polydactyly must be due to processes in the germ of which we are totally ignorant. Gougerot (lxxxvi.), a case of *absence of the fifth digit* and reduction of the carpus by fusion of a rudimentary unciform with the os magnum. There was also fusion of the semilunar and trapezium. Féré and Perrin (lxxxvii.) deal with a very slight but not uncommon malformation, in the shape of lateral inclination of fingers towards the axis of the hand or towards a line parallel to this axis, passing between the third and fourth fingers. Digitus minimus valgus may possibly be a stigma of degeneration. The authors have examined 180 male lunatics who exhibited this condition of little finger 48 times on both sides (26·66 per cent.), 19 times only on the left (10·55 per cent.), and 3 times on the right (1·66 per cent.), making in all 70 cases (38·88 per cent.). One hundred work-people of different kinds, who might be considered mentally normal, were examined as a comparison. The abnormality was found 12 times on both sides, 6 times on the left only and once on the right, making 19 cases in all. Lacasse and Lerembourg (lxxxviii.), *congenital dislocation of the hip* observed in a still-born fœtus. The pelvis was very asymmetrical, being obliquely

oval, the left side atrophic. The left acetabulum was atrophied, and the cotyloid ligament flattened posteriorly by the pressure exerted upon it by the head of the femur. The capsule was relaxed and there was a ligamentum teres. The head of the femur was atrophied, and the bone itself shorter than its fellow. The head lay on the posterior part of the cotyloid ligament. It was quite clear that the dislocation had not been caused by any accident at the time of delivery. CAUBERT and MERCADÉ (lxxxix.), a paper on *congenital hypertrophy of the toes*, which condition usually affects the second, whilst in macrodactyly it is usually the third digit which suffers. ANTONELLI (xc.), a case of partial *defect of the fibula*.

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AN UNUSUAL DISPLACEMENT OF THE HEART. By DAVID WATERSTON, M.A., M.D., *Senior Demonstrator of Anatomy, University of Edinburgh.*

THE specimen which showed this condition was obtained by Colonel Bannerman, I.M.S., and was sent by him to Professor D. J. Cunningham, who kindly gave me the opportunity of examining it.

Though the specimen is very incomplete, on account of the circumstances in which it was obtained, yet it clearly shows a most unusual displacement of the heart, and for that reason deserves to be placed on record.

The history attached to it is, that the specimen was obtained from a wild teal (Querquedula) which formed one of a bag shot (Nov. 1904) by Mr J. Fisher, Indian Forest Service, in the Thana jungles, near Bombay. The animal showed no trace of any abnormality externally, and was prepared and cooked for the table; but the carver, on making a cut into the breast, exposed an unusual structure lying embedded in the substance of the pectoral muscles. Recognising that there was some unusual abnormality, he removed the pectoral muscle and the enclosed structure, and preserved them in dilute alcohol.

The specimen as it came under my observation consisted of a fleshy mass about 2½ inches long, 1 inch wide, and ½ inch thick, consisting principally of the great pectoral muscle, and some incisions had been made which subdivided the specimen.

In the very centre of the muscular mass was an oval cavity, measuring ¾ of an inch in length by ½ inch wide, and lying in this hollow was a structure which there was no difficulty in recognising as a well-formed avian heart. No fibrous pericardium was present, but the walls enclosing the cavity were smooth and polished in character, and the surface of the heart was apparently covered by a smooth epicardium. The heart itself appeared to be perfectly normal, and from its anterior end gave off the great vessels, which, however, had been cut short and could not be traced.

As the sternum was not present, I had no opportunity of examining its condition. Mr Fisher, however, made the following note regarding it:—

"The breast bone . . . was normally formed, and both sides alike. There was no open split, and I don't think a closed one. The arteries passed round the front of the breast bone and through the aperture to

the inside, where they connected with the lungs on the inner side of the backbone."

I am not aware of any description of any similar condition, and the origin of the misplacement in obscure.

It is, however, interesting to note that the bird was apparently quite able to take to flight, and that the movements of the heart were not arrested by the contractions of the surrounding muscular tissue; and this fact was specially noted by Mr Fisher, who states that the bird flew strongly, and, for his kind, fast, circling about for some five minutes before coming in his direction.

JOURNAL OF ANATOMY AND PHYSIOLOGY

ON THE ORIGIN OF VERTEBRATES, DEDUCED FROM THE STUDY OF AMMOCŒTES.

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PART XIII.—THE ORIGIN OF THE NOTOCHORD AND ALIMENTARY CANAL.

IN a series of papers published in this Journal I have developed my theory of the origin of vertebrates, and have compared, step by step, every organ in the arthropod with the corresponding organ in the vertebrate, and shown how one after another each has fitted into its right place, on the assumption that the arthropod has given rise to the vertebrate without any reversal of surfaces, an assumption which necessitates the formation of a new alimentary canal for the vertebrate. In my last paper I gave my reasons for believing that the laws of embryology did not run counter to such an assumption, but that on the contrary the mode of development of the neural canal in the vertebrate was in exact accordance with that of the scorpion alimentary canal, on the supposition that the latter no longer functioned as an alimentary canal.

All that remains now to be done is to attempt to form some idea how the new alimentary canal came into existence, and with that question the formation of the notochord is closely associated: for in this respect embryologists agree. The two structures must therefore be considered together, and as according to the hypothesis they are both new structures essentially belonging to the vertebrate, it is not possible to adopt the comparative anatomy plan hitherto used. It is impossible, therefore, to have the same feeling of surety in the conclusions drawn as in the case of all the other organs hitherto considered, for a close similarity in the structural and topographical anatomy of a whole series of organs in two sets of animals is the

very strongest and surest foundation for a genetic relationship between those two sets of animals.

The Origin of the Notochord.

Any suggestion, then, as to the origin of the notochord is on a different footing to the rest of this story; all the organs of the arthropod have already been allocated; where the notochord is situated in the vertebrate there is nothing but a gap in the invertebrate, but the position of that gap can be settled with great accuracy from the previous comparison of organs in the two groups; hence it is possible to deduce a somewhat plausible scheme of the origin of the notochord.

Let us, then, see what is the necessary position of the notochord according to the scheme advanced in previous chapters.

It may be taken for granted that the notochord was originally a tube,—a tube therefore which extended from the infundibulum to the end of the body in the middle line. This tube moreover was situated immediately ventral to the whole of the central nervous system posterior to the infundibulum. Translate this into the language of the arthropod and it denotes a tube on the mid-ventral surface of the body which extended from mouth to anus. In other words, the mid-ventral surface of some arthropod ancestor formed for some purpose a tube which extended from mouth to anus. Is there any evidence that such a tube might have been formed?

As already frequently stated, Apus and Branchipus are the two living arthropods which most nearly resemble the extinct Trilobites. The beautiful specimens of the Triarthus found by Beecher give an idea of the under surface of the Trilobite such as has never been obtained before, and demonstrate how closely the condition of things found in Apus was similar to that occurring in the Trilobites. In both cases the mid-ventral surface of the animal formed a deep groove which extended the whole length of the animal: on each side of this groove in Apus are closely set the gnatho-bases of the appendages, in such a manner that the groove can be easily converted into a canal by the movements of these bases,—a canal which, owing to the great number of the appendages and their closeness to each other, can be completely and efficiently closed.

All those who have seen Apus in the living state assert that this canal so formed is actually used by the animal for feeding purposes. By the movements of the gnatho-bases food is passed up from the hind end of the animal along the whole length of this ventral canal to the mouth, where it is taken in and swallowed. In this way Apus has been seen to swallow its own eggs.

In the Trilobites there is a similar deep channel formed by the mid-ventral surface, similar gnatho-bases, and closely set appendages, and the membrane of this ventral groove was extremely thin.

Here, then, in the very group of animals which were the progenitors of the presumed Palæostracan ancestor of the vertebrate—a group which is characterised by its extensive prevalence and its enormous variety of form during the great Trilobite era—the formation of a mid-ventral canal out of this deep ventral groove is seen to be not only easy to imagine, but most probable, provided that a necessity arose for such a conversion.

For what purpose might such a tube have been formed? I would suggest that it might have acted as an accessory food channel; inefficiently in all probability but still sufficiently to give some advantage in the struggle for existence to those members of the group who were able in this way to supplement their intake of food.

Three points may be urged in favour of this view.

1. The evidence of Apus proves that food does pass along a ventral channel of this kind.

2. Miss Alcock has proved that the skin of the surface epithelium of Ammocœtes and of the cray-fish has the power of digesting fibrin; therefore a channel so formed may easily have possessed digestive powers.

3. The evidence of the Trilobite proves that the membrane of such a channel was very thin, and absorption therefore might easily have taken place.

Further, again, the possibility of the formation of such an adjuvant accessory alimentary canal, at a time when the growth of the central nervous system was severely narrowing the calibre of the ordinary food passage, would be increased if the animal in question fed mainly upon the blood of other animals; for such food requires but little digestion, and absorption might easily occur when once the tube was formed.

As far as the evidence permits us to judge, it seems a necessity that a tube formed in such a way as suggested should have been formed at a stage when all the appendages were free along the whole length of the body: before therefore the formation of an accessory oral chamber.

Such a stage would be represented phylogenetically by a late period of the Trilobite stage, and might be called the Trilobite chordate stage. Its formation would be represented in the diagram (figs. 1A, 1B).

This conception that the notochord originated as a median groove receives support from the evidence of its origin in Amphioxus, where it originates distinctly from a groove in the wall of the future alimentary canal. Also, if the notochord arose as suggested, it arose originally as a markedly segmented organ, for it originated from the segmented ventral

surface and the basal parts of the paired appendages of the animal. On this view its unsegmented character must have been a later acquisition after it had become a gut tube.

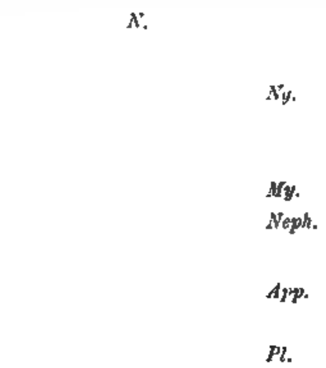

FIG. 1A.

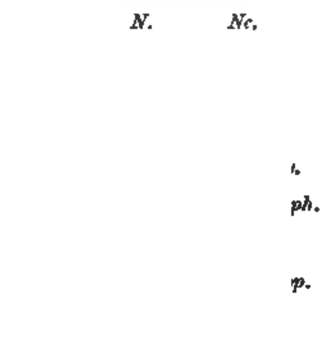

FIG. 1B.

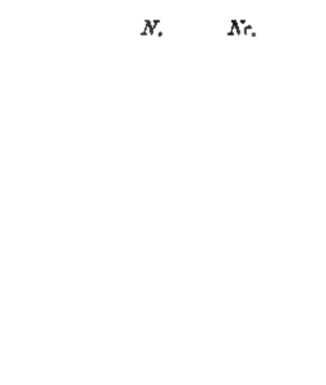

FIG. 1C.

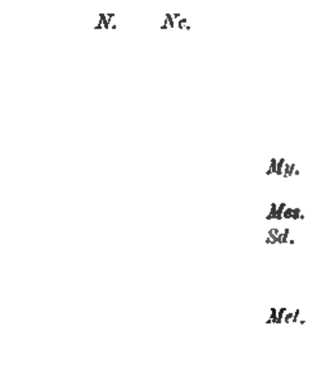

FIG. 1D.

FIG. 1A.—Diagram of section through a Trilobite-like animal.

B.—Diagram to illustrate the suggested formation of the notochord from a ventral groove.

C.—Diagram to illustrate the suggested formation of the post-branchial gut by the continuation of the same process of ventral-groove formation, combined with obliteration of appendages and growth of pleural folds.

D.—Diagram to illustrate the completion of the vertebrate type by the meeting of the pleural folds in the mid-ventral line with the obliteration of the atrial cavity and the conversion of the ventral groove into the closed alimentary canal.

Al., alimentary canal; *N.*, nervous system; *My.*, myotome; *Pl.*, pleuron; *App.*, appendage; *Neph.*, nephrocele; *Met.*, metacœle; *Sd.*, segmental duct, *Mes.*, mesonephros; *At.*, atrial chamber; *Nc.*, notochord; *H.*, heart; *F.*, fat body; *Ng.*, notochordal groove.

(These diagrams are intended to complete the diagrams on p. 194 of my previous paper, Part XI. of this series, which, as stated there, were purposely left incomplete.)

In Amphioxus evidence of segmentation has been found of a character so extraordinary that it is very doubtful what its meaning really is.

At intervals fairly regular the sheath of the chorda is interrupted on each side of the mid-dorsal line by a series of holes, and at each hole corresponding bundles of fibres are seen to pass to the surface of the spinal cord from the tissue of the cord, while the hole in the sheath is filled up with fibres passing towards the spinal cord from the tissue of the notochord itself. The appearance resembles a series of paired ventral roots to the notochord which penetrate the sheath to pass to the innermost notochord tissue, and such Miss Platt[1] conceives them to have been. On the other hand, according to Joseph[2] there is no actual passage of fibres from the spinal cord into these holes, and the fibres do not appear to be nervous in nature. Still, whatever is the ultimate verdict as to these fibres, there remains the suggestive fact of the spaces in the notochordal sheath and of the corresponding projecting root-like fibres of the spinal cord. The whole appearance gives the impression of some former connection, or rather series of connections, between the spinal cord and the notochord such as would have occurred if nerves had once passed into the notochord. On the other hand, such nerves were not arranged segmentally with the myotomes, for, according to Joseph, in the middle of the animal ten to twelve such holes occur in one body segment.

As far, then, as the invertebrate is concerned, it is not out of the question to imagine the formation of such an accessory food channel.

Turning now to the vertebrate, the evidence here is still more in support of such a view, as is seen from the following considerations.

The notochordal tube is unsegmented, although the vertebrate is markedly segmented. But in all segmented animals the only unsegmented tube which extends the whole length of the body from mouth to anus is invariably the gut. In the vertebrate there are three such tubes: (1) the gut itself, (2) the central canal of the nervous system, and (3) the notochordal tube.

The first is the present gut, the second the gut of the invertebrate ancestor, and the third the tube in question.

Again, the structure of the notochord is something *sui generis*. Its lumen is filled up with a tissue which has nothing whatever to do with bone or cartilage or any of the usual supporting tissues; a tissue whose only counterpart, hitherto found among the invertebrates, occurs invariably in disused portions of the alimentary canal. Thus in Balanoglossus, in Cephalodiscus, in Actinotrocha, in all these animals, one or other portion of

[1] J. B. Platt, *Anat. Anzeiger*, 7 Jahrgang, 1892, p. 282.
[2] H. Joseph, *Zeitsch. f. wissent. Zool.*, vol. lix., p. 511.

the alimentary canal has more or less lost its lumen, its lining cells have become vacuolated, with the result that this portion of the canal has been converted into a tissue somewhat resembling that of the notochord. Such a fetish has the notochord become, that actually classifications have been based on this resemblance of the notochordal tissue to degenerated portions of the gut of these animals, regardless of the fact that the notochord extends along the length of the body of the animal, and that therefore tissue resembling that of the notochord found in isolated diverticula of the alimentary canal of some or other invertebrate, suggests only that the notochord may have once functioned as an alimentary canal, the walls of which, after the cessation of such functions, have become converted into this peculiar tissue as in these other cases.

Nc.
Nch.
Al.
Hy.

Fig. 2.—Diagram to show the meeting of the four tubes in such a vertebrate as the lamprey. *Nc.*, neural canal with its infundibular termination; *Nch.*, notochord; *Al.*, alimentary canal with its anterior diverticulum; *Hy*, hypophysial or nasal tube, *Or.*, oral chamber closed by septum.

Thus we see Amphioxus is called Cephalochorda because the notochord projects beyond the central nervous system; the Tunicates, Urochorda, because it is confined to the tail; the Enteropneusta, Hemichorda, because this tissue is confined to a small diverticulum of the gut; Actinotrocha and Phoronis, Diplochorda, because two separate portions of the gut are transformed in this way. This exaggerated importance given to any tissue, resembling in structure that of the notochord, is believed in by many of those who profess to be our teachers on this subject, the very men who can deliberately shut their eyes to the plain reading of the story of the pineal eyes, and say, "In our opinion this pineal organ was not an eye at all."

The only legitimate inference to be drawn from the similarity of structure between the notochord and these degenerated gut diverticula, is that the structure of the notochord may have arisen in the same way, and

therefore the notochord may have once functioned as a gut. Yet another circumstance in favour of this suggestion is the very striking position of the anterior termination of the notochord. It terminates at the point of convergence of three structures:—

(1) The tube of the hypophysis or nasal tube.
(2) The infundibulum or old mouth termination.
(3) The notochord tube.

To these may be added, according to Kupffer, in the embryonic stage, the anterior diverticulum of the gut (fig. 2).

This is a very significant point. Here originally, in the invertebrate stage, the olfactory passage opened into the old mouth and œsophagus. Here, finally, in the completed vertebrate the same olfactory passage opens into the new pharynx. In the stage between the two it may well have opened into an intermediate gut, the notochordal tube, its separation from which would leave the end of the notochord blind, just as it had already left the end of the infundibulum blind.

The Origin of the Alimentary Canal.

In close connection with the notochord is the alimentary canal. Any explanation of the one must be of assistance in explaining the other.

According to prevalent embryological teaching, the body is formed of three layers, epiblast, hypoblast, and mesoblast, and the gastræa theory of the origin of all metozoa implies of necessity that the formation of every individual commences with the formation of the gut. For this reason the alimentary canal must in every case be regarded as the earliest formed organ, however late in the development it may attain its finished appearance. Hence the notochord is spoken of as developed from the mid-dorsal wall of the alimentary canal. It is possible to look at the question the other way round, and consider that organ whose development is finished first to be older than the one still in process of making. In this case it would be more right to say—A ventral extension of the tissue, which gives rise to the notochord, takes place and forms the alimentary canal.

It is, to my mind, perfectly possible, and indeed probable, that the formation of the vertebrate alimentary canal was a repetition of the same process as had already led to the formation of the notochordal tube.

The formation of the anterior part of the alimentary canal in Ammocœtes at the time of transformation strongly suggests the marked similarity of the two processes.

Of all the startling surprises which occur at transformation, this formation of a new anterior gut is the most startling. From the oral chamber of

Petromyzon two tubes start: the one leads into the gill chambers, is known as the bronchus, and is entirely concerned with respiration; the other leads without a break from the mouth to the anus, has no connection with respiration, and is the alimentary canal of the animal. Any one looking at Petromyzon would say that its alimentary canal was absolutely non-respiratory in character. Before transformation, this kind of alimentary canal commences at the end of the respiratory chamber, from here to the anus it is of the same character as in Petromyzon, but in Ammocœtes the non-respiratory anterior part simply does not exist: the whole anterior chamber is both respiratory and affords passage to food. This part of the alimentary canal of the adult is formed anew. We see, then, here the formation of a part of the alimentary canal taking place not in an embryo full of yolk, but in a free-living, independent, grown-up larval form in which all yolk has long since disappeared: a condition absolutely unique in the vertebrate kingdom, but one which more than any other may be expected to give a clue to the method of formation of a vertebrate gut.

The formation of this new gut can be easily followed at transformation, and was originally described by Schneider. His statement has been confirmed by Nestler, and its absolute truth has been demonstrated to me again and again by Miss Alcock, in her specimens illustrative of the transformation process. First, in the mid-dorsal line of the respiratory chamber a distinct groove is formed, the edges of which come together and form a solid rod. This solid rod blocks the opening of the respiratory chamber into the mid-gut, so that during this time of the transformation no food can pass out of the pharyngeal chamber. A lumen then begins to appear in this solid rod at the posterior end, which steadily advances mouthwards until it opens into the oral chamber and thus forms an open tube connecting the mouth with the gut.

Here, then, is the foundation of a new gut on very similar lines to that of the notochord, by the conversion of a groove into a tube: still more suggestive is it to find that the tube so formed has no appearance whatever of segmentation, it is as unsegmented as the rest of the gut, although, as is seen in Pl. III. of my paper on the origin of the branchial segmentation,[1] the dorsal wall of the respiratory chamber from which it arose is as markedly segmented as any part of the animal.

Here under our very eyes, in the course of a few days or weeks, an object lesson in the process of the manufacture of an alimentary canal is carried out and completed, and the teaching of that lesson is: a gut tube may be formed in the same way as the notochord tube, by the conversion of a grooved surface into a canal, and that gut tube so formed, like the noto-

[1] This Journal, vol. xxxiii., p. 154.

chord, loses all sign of segmentation, even although the original grooved surface was markedly segmented.

The suggestion then is, the new gut may have been formed by a repetition of the same process which had already given origin to the notochord.

Let us consider what is the teaching of the vertebrate as to the origin of the gut.

Throughout the whole argument of these papers, the one fixed landmark to which all other comparisons must be referred is the central nervous system. The innervation of the gut is therefore the first question to be investigated.

At the very outset we are met here with a difficulty which is not apparent in the case of the innervation of ordinary striated muscle: the difficulty due to the gut being innervated with inhibitory as well as motor nerves. In all morphological discussion it is tacitly understood that, with the exception of the heart, the phrase, "innervation of muscle," means those nerves which cause the muscle to contract; those which cause the muscle to relax are not considered.

In the case of the alimentary canal physiological research has shown that the inhibitory nerves may arise from very different parts of the central nervous system to the motor nerves; therefore any morphological argument applying to the one need not apply to the other. The morphological meaning of an inhibitory nerve is at present difficult to understand; the presence also of Auerbach's plexus along the whole length of the intestine, especially in view of the recent experiments of Magnus, makes it still more difficult to estimate correctly the meaning of the gut innervation.

If the attention be fixed only on those nerves which cause contraction, the motor nerves of the gut, a distinctly suggestive state of affairs is disclosed.

The whole of the gut to the end of the small intestine is innervated by the vagus nerve.

The whole of the colon and rectum is innervated from the sacral region of the cord.

Between these two regions a small band of muscle is found constituting the ileo-colic sphincter—formerly called the ileo-colic valve—which receives its motor supply from the thoracic region of the cord.

The interpretation of this striking innervation is as follows: The vagus is the branchial nerve, the nerve of the branchial chamber; the limit of its distribution indicates the limit of the extension of the original branchial area.

The large intestine with its innervation from the sacral end represents the cloacal region, and the independence of the innervation between these

two parts of the gut means that the cloacal region has always been entirely independent of the branchial.

Between the branchial and cloacal regions a very small portion existed confined to the ileo-cæcal sphincter, innervated by nerves from the thoracic-lumbar region of the cord.

Such innervation seems to me to suggest that originally the vertebrate consisted, as far as its gut was concerned, of a prosomatic and mesosomatic (branchial) region, close behind which came the cloaca and anus. Between the two there was a short metasomatic region (possibly pronephric), so that the respiratory chamber did not open directly into the cloaca.

Such an interpretation is, I think, borne out by the study of the most ancient forms of fish. In Bothriolepis, according to Patten, and in Drepanaspis, according to Traquair, the cloacal region and anus follow immediately upon the posterior end of the head shield, *i.e.* immediately after that region which presumably contained the branchiæ. Similarly on the invertebrate side, all those forms which resembled Limulus must have possessed a very short region between the branchial and cloacal parts of the body. The original cloacal part of the vertebrate gut may well have been the original cloaca of the arthropod, into which its intestine emptied itself, especially when we see the tendency of the scorpion group of animals to form an accessory cloacal pouch known as the stercoral pouch or pocket.

Again, it is striking to see how, in certain of the scorpion group, *e.g.* Thelyphonus and Phrynus, there is a caudal massing of the central nervous cells as well as a cephalic massing, so that their central nervous system is composed of a cephalic and caudal brain. These two brains are connected together by commissures extending the whole length of the body, in which I have been unable to find any sign of ganglion cells. What this caudal brain innervates I do not know; it is, to my mind, a matter worth further investigation, especially as there are many indications in the vertebrate that the lumbo-sacral region of the cord possesses higher functions than the thoracic region.

The suggestion, then, is that the vertebrate gut was formed, as far as its anterior portion was concerned, in the manner already sketched out, of an oral and respiratory chamber; between the termination of this respiratory chamber and the anus a short tube was formed connecting the respiratory part of the new gut with the cloacal part of the old gut.

I imagine that this connection was originally in the form of an open groove, as already explained for both notochord and the anterior part of the gut itself in Ammocœtes; an open groove formed, again, from the mid-ventral surface of the body, on each side of which were the remnants of the pronephric appendages. By the closure of this groove ventrally and

the growing round of the pleural folds, as already indicated, the remains of the pronephric appendages are indicated by the segmental duct and the form of the vertebrate body is attained.

Even in the branchial region the same kind of thing must, I think, have occurred: the grooved ventral surface became a tube on each side of which were lying in regular order the insunk branchial appendages, the whole being subsequently covered by the pleural folds to form an atrial chamber. A tube thus formed from the grooved ventral surface would carry with it to the new ventral surface the longitudinal venous sinuses and thus form in the way already suggested the heart and ventral aorta. Posterior to the heart in the pronephric region, the same process would give rise to the subintestinal vein.

In conclusion, I will endeavour to illustrate crudely the way in which, on my theory, the notochord and vertebrate gut may have been formed; the agencies at work being in the main two, viz., the dwindling of appendages as mere organs of locomotion, and the conversion of a ventral groove into a tube.

I imagine that, among the Protostraca, forms were found somewhat resembling Trilobites with markedly Polychætan affinities, which like Apus possessed a deep ventral groove from one end of the body to the other, and also pleural fringes, as in many Trilobites. This might be called the Trilobite stage (fig. 1A).

This groove became converted into a tube and so gave rise to the notochord, while the appendages were still free and the pleuræ had not met to form a new ventral surface. This might be called the chordate Trilobite stage (fig. 1B).

Then, passing from the Protostracan to the Palæostracan stage, the oral and respiratory chambers were formed, not communicating with each other, in the manner described in these papers, a ventral groove in the metasomatic region being the only connection between respiratory chamber and cloaca. This might be called the chordate Palæostracan stage (fig. 1C).

Finally, with the conversion of this groove into a tube, the opening of the oral into the respiration chamber, and the formation of an atrium by the ventralwards growth of the pleural folds, the formation of a vertebrate was completed (fig. 1D).

In my own mind I picture to myself an animal which possessed Eurypterid and Trilobite characters combined, in which a notochordal tube had been formed in the way suggested, and a respiratory chamber which communicated with the cloaca by means of a grooved channel along the mid-ventral line of the metasomatic portion of the body. On each side of this channel were the remains of the metasomatic appendages (pro-

nephric). The whole was enveloped in the pleural folds, which probably at this time did not yet meet into the middle line to form a new ventral surface. This respiratory chamber, owing to the digestive power of the epidermis, assisted in the process of alimentation to such an extent as to supersede the temporary notochordal tube, with the effect of bringing about the conversion of the metasomatic groove into a closed canal, and so the formation of an alimentary tube continuous with the respiratory chamber. The amalgamation of the pleural folds ventrally completed the process, and so formed an animal resembling the Cephalaspids, Ammocœtes, or Amphioxus.

I have endeavoured in this paper to make some suggestions upon the origin of the notochord and the vertebrate gut in accordance with my theory of the origin of vertebrates. I feel, however, strongly that these suggestions are much more speculative than those put forward in the previous papers of this series, and of necessity cannot give the same feeling of soundness as those based directly upon comparative anatomy and histology. Still, the fact remains that the origin of the notochord is at present absolutely unknown, and that my speculation that it may have originated as an accessory digestive tube is at all events in accordance with the most widely spread opinion that it arises in close connection with an alimentary canal.

With this paper I propose to terminate this series of papers in this Journal. I am aware that in the course of these papers I have promised at some time to consider separately the vascular and lymphatic systems and the external covering, and I still hope to be able some day to publish something on these subjects. At present, however, I am engaged in putting the whole story into book form, and until that is accomplished I am not likely to add to this series. Further, the shape of the Journal has been altered so that subsequent communications on this subject would no longer bind up with my previous parts.

In conclusion, I desire to thank the editors of the *Journal of Anatomy and Physiology* for their true scientific spirit in so freely allowing the columns of their Journal to be the means of publication of a series of heretical papers at a time when it seemed to me it would otherwise have been difficult in England to get a hearing at all.

The series in question consists of thirteen parts, published as follows:—

THE ORIGIN OF VERTEBRATES DEDUCED FROM THE STUDY OF AMMOCŒTES.

Part I. The Origin of the Brain. Vol. xxxii. p. 513.
„ II. The Origin of the Vertebrate Cranio-facial Skeleton. Vol. xxxii. p. 553.

Part III. The Origin of the Branchial Segmentation. Vol. xxxiii. p. 154.
„ IV. The Thyroid or Opercular Segment: the meaning of the Facial Nerve Vol. xxxiii. p. 638.
„ V. The Origin of the Pro-otic Segmentation: the meaning of the Trigeminal and Eye-muscle Nerves. Vol. xxxiv. p. 465.
„ VI. The Old Mouth and the Olfactory Organ: the meaning of the First Nerve. Vol. xxxiv. p. 514.
„ VII. The Evidence of Prosomatic Appendages in Ammocœtes, as given by the Course and Distribution of the Trigeminal Nerve. Vol. xxxiv. p. 537.
„ VIII. The Palæontological Evidence: Ammocœtes a Cephalaspid. Vol. xxxiv. p. 562.
„ IX. The Origin of the Optic Apparatus: the meaning of the Optic Nerves. Vol. xxxv. p. 224.
„ X. The Origin of the Auditory Organ: the meaning of the VIIIth Cranial Nerve. Vol. xxxvi. p. 164.
„ XI. The Origin of the Vertebrate Body-cavity and Excretory Organs: the meaning of the Somites of the Trunk and of the Ductless Glands. Vol. xxxvii. p. 168.
„ XII. The Principles of Embryology. Vol. xxxix. p. 371.
„ XIII. The Origin of the Notochord and Alimentary Canal. Vol. xl. (third series, vol. i.) p. 305.

THE CEREBELLUM OF PETROMYZON FLUVIATILIS. By W. B. CLARK, M.B., B.S. Lond. (*From the Senckenberg Neurological Institute; Director — Professor Edinger, Frankfurt-a-Main.*) (PLATE XXVII.)

THE work performed at the Senckenberg Neurological Institute at Frankfort is, generally speaking, based upon the following principles: "There must be a number of anatomical mechanisms which are alike present in all vertebrates: those which make possible the simplest expressions of the activity of the central nervous system. It is only necessary to find that animal, or that stage of development of any animal, in which this or that mechanism appears in so simple a form that it may be completely understood.

"Once one has perfectly established anywhere the relation of such a mechanism—*e.g.* a nerve bundle or a cellular structure—one is usually able to readily find it again, even where, through adventitious matter, it is made more or less obscure. The discovery of such fundamental features of brain and structure appears to be the next and most important task of brain morphology. Once we know them, it will be easier to understand the complicated mechanisms with which the more highly organised brain performs its function."

In accordance with this train of thought, I have investigated the bundles of fibres which are peculiarly characteristic to the cerebellum, so characteristic indeed that they can never be lacking in its plan of construction. The cerebella of mammals and birds, being highly developed organs, are not adapted to investigations of that kind. The most obvious course is that of studies of comparative anatomy on a broad basis. It is the one adopted by Bianchi. Since in his work, which appeared in 1903, he was enabled to fully avail himself of the researches of his predecessors, especially on the brains of fishes and amphibians, I only mention his own results. As far as the previously existing literature on the subject is concerned, I refer the reader to Bianchi's original publication. It is notably the cerebellum of the Teleostians, which has been frequently studied since Mayser, then that of the frog, which Wlassak made the object of a most thorough investigation.

Bianchi summarises his results. In fishes he found the following tracts:—

Afferent from the spinal cord, from the medulla, from the spinal ganglia, and from the sensory cranial nerves X. to V.

Efferent to the mesencephalon and thalamencephalon.

In *amphibians*, taking Bufo vulgaris as an example, he describes:—

Afferent fibres from the spinal posterior nerve roots and from the Xth, IXth, VIIIth, and Vth cranial nerves that go directly to the cerebellum and end in the granular layer. Fibres from Clarke's column and from sensory nuclei in the medulla, entering the cerebellum as arcuate fibres, terminating in the medullary layer and helping to form the plexus rampicanti.

Fibres by the anterior peduncle to the mesencephalon and the thalamencephalon, both crossed and uncrossed, and fibres to the tegmentum.

These he again summarises into two fundamental groups:—

Afferent from the sensory spinal and bulbar nerves, from the cells of the dorsal columns, and from the sensory region of the bulb and spinal cord.

Efferent to the mesencephalon and thalamencephalon.

In *birds* he describes:—

Afferent from the posterior and lateral columns.
From the sensory nuclei of the medulla.
Tecto-cerebellar tract.

Efferent $\begin{cases} \text{Cerebello-thalamic crossed.} \\ \text{Cerebello-mesencephalic direct.} \\ \text{Descending cerebello-spinal.} \end{cases}$

Edinger (8) has tried to find the fundamental structures by studying a simple but highly developed brain, namely, that of a shark (*Scyllium canicula*). This animal is admirably suitable, as it possesses no pons, probably no olive, hence no olivary tract and no tracts from the fore-brain to the cerebellum. Though at first sight this cerebellum appears to be a somewhat complicated structure, it is in reality quite simple, compared to the cerebella of the higher vertebrates. He found that the convolutions consisted of a simply built lamina, and that the only thing to complicate it was the existence of a nucleus at each side, just at the entrance of the brachia.

He describes the following connections:—

Anteriorly, a crossed and an uncrossed tract to the thalamus. Posteriorly, a small tract to the bulb and spinal cord, and probably a ventral descending tract to the tegmentum. But the great bulk of the entering fibres comes from the sensory nerve roots, *e.g.* Vth, VIIth, VIIIth, IXth, and Xth cranial nerves, and the author concludes by saying: "The cerebellum of the Selachians is essentially nothing but the end apparatus

of the direct sensory tracts, and all other fibres which connect it with other parts play anatomically only a small rôle."

The course which I have pursued is not the comparative.

There are cerebella which retain the simple structure of an embryonic lamina all through life. As far as we know, this thin, unconvoluted lamina which bridges over the medulla, possesses the same structure in all vertebrate embryos. Such lamellated cerebella persist throughout life in Petromyzon, in Amphibians, and in the Lacertidæ. Edinger has shown how this lamina grows and gets arched dorsally, forming a small cerebellar lobe in the swimming reptiles (crocodiles, turtles, etc.), as these animals certainly require a higher degree of equilibration. Already in fishes, Teleostians and Selachians, the simple embryonic lamina has given way to a highly convoluted cerebellum, probably from the requirements of equilibration, but in all amphibians the cerebellum remains in the embryonic state throughout life.

A large number of nerve fibres which enter these simple cerebella are without a medullary sheath. Hitherto we did not possess any means of tracing these. Nowadays, however, we are enabled to stain such fibres by the admirable nitrate-of-silver methods of Ramon y Cajal and of Bielschowski; therefore it is worth retesting the accuracy of the work done by E. Gaupp and Wlassak for the amphibians, and by Edinger (5) for the brain of the lizard.

All we have learned hitherto about the connections of these fibres can only be a part of the whole. I myself have investigated two remotely different species by means of the Bielschowski method, *i.e.* the cerebellum of Petromyzon and that of Siredon pisciformis, the latter a little less thoroughly on account of lack of material.

The first description of the structure of the cerebellum of Petromyzon that I have been able to find was published in 1879 by Jeleneff (1). In this work he describes the histology of the cerebellum but not its connections. He describes the cerebellum as consisting of two parts, an outer fibrous layer and an inner cellular; the latter consisting of an epithelial layer, then a layer of round cells three or four deep, then a regular layer of large cells which he regards as Purkinje cells of the higher vertebrates.

Ahlborn's (2) classical work on the brain of Petromyzon (1882) does not describe the histology or connections of the cerebellum.

In the same year Rohon (4) published *The Origin of the Nervus Acusticus in Petromyzon.* In this work he surmises the existence of a cerebellar root of the VIIIth nerve, but did not find it.

In 1899 Schaper (3) described the histology of the cerebellum, evidently not knowing of Jeleneff's work: he finds much the same structures as his predecessor did.

In 1902 Johnston (6) published his work on the brain of Petromyzon, based

chiefly on the Golgi method: in this most excellent work he has very thoroughly described the histology and connections of the cerebellum.

He describes the following connections:—

Cerebellar roots of the Vth (VIIth and VIIIth) nerves.
Tractus lobo-cerebellaris (Tr. cerebello-thalamicus).
Arcuate fibres running ventrally (Tr. tegmento-cerebellar).
Arcuate fibres running to unsulate commissure.

The cerebellum of Petromyzon consists of a thin lamina bridging over the medulla and uniting laterally with the crista acustica. This lamina consists of a frontal molecular layer, and a caudal cellular or granular layer. The frontal layer is composed chiefly of the processes from the Purkinje and other cells. Some fibres of the tracts enter here: near the middle line quite a plexus of fibres is formed. The granular layer consists caudally of a row of epithelial cells, then several rows of round cells, and scattered irregularly among the round cells, and partly in medullary layer, are the large (?) Purkinje cells. Most of the fibre tracts enter this part of the cerebellum. We have nothing to add to Johnston's histological description, based essentially on Golgi preparations.

The cerebellum is connected frontally by a tract to the thalamus, and by a second to the tectum opticum; caudally it is connected by tracts to the bulb, tegmentum, and probably the spinal cord, and it receives also the roots of the large cranial sensory nerves (V., VII., VIII., and X.). The trochlearis entering it from the mid-brain, lies in the substance of the cerebellum, not anterior, as in other vertebrates: it runs downwards and backwards, crosses the middle line, and emerges from the dorso-lateral aspect of the cerebellum.

TRACTUS CEREBELLO-THALAMICUS. (Fig. 1.)

This is a small tract of fine fibres which seems to originate from a group of large cells indistinguishable from the Purkinje cells, which may perhaps represent the dentate nucleus of the higher vertebrates (fig. 2). It leaves the cerebellum on its ventral aspect near the median line, and runs ventrally towards the thalamus, where it crosses the middle line close to the decussation of the oculo-motor and gets lost in the thalamus. This tract is described by Johnston, and called by him the tractus lobo-cerebellaris.

TRACTUS TECTO-CEREBELLARIS. (Fig. 2.)

This tract, which is a fine-fibred tract, forms the chief anterior connection of the cerebellum, and lies near the median line. Its fibres pass more or less horizontally from the tectum at the level of the deep medullary

layer, and bend dorsally near the median line of the cerebellum. This tract is not described by Johnston, in fact he remarks on its absence.

Tractus Tegmento-Cerebellaris. (Fig. 1.)

This is a small tract of fine fibres which leaves the cerebellum from its ventral and internal aspect and runs almost directly ventrally to the median line, when it crosses and gets lost in the tegmentum of the oblongata. This tract is probably what Johnston describes as the arcuate fibres that run directly ventrally.

Tractus Spino-Bulbo-Cerebellaris. (Fig. 3.)

This is a medium-sized tract, the origin of which is very hard to trace. It probably comes from the spinal cord: this I have not been able to make out with certainty, but it certainly comes from the bulb. Its fibres are seen in transverse sections as a bundle running dorsally near the lateral surface of the medulla, external to the tractus tecto-spinalis lateralis, and entering the cerebellum along its lateral aspect: a considerable portion of its fibres cross the median line.

This tract does not appear to be described by Johnston.

Cerebellar Root of Trigeminus.

These fibres form a large portion of the medullary layer of the cerebellum. They are for the most part thick, and enter the cerebellum on its dorsal and external surface. They form part of the caudal connections, and run antero-internally to the middle line, where they cross to the other side and end. The fibres from the fifth nerve in our sections appear to come entirely from the big-root fibres lying outside the medulla, and no tract could be made out coming from fibres lying in the substance of the medulla, as described by Johnston.

Cerebellar Root of Sensory-Facial and Acustic Nerves. (Figs. 1, 3.)

As I have been unable to differentiate between the fibres of the sensory-facial and the acusticus, going to the cerebellum, I shall describe them together and refer to them as cerebellar root of acusticus.

This tract, which consists of mediumly large fibres, is the largest tract entering the cerebellum. The fibres enter the crista acustica just posterior to the main root of the acusticus, and run forwards ventral to the acustic

nucleus, and at the level of the cerebellum bend inwards to enter it on its ventral aspect. The fibres then cross the middle line and appear to end by breaking up in the most lateral parts of the cerebellum, the crossed part lying amidst the endings of its fellow of the opposite side; this is the biggest decussation in the cerebellum.

As there is no nucleus of origin to be found in the cerebellum, this leads one to suppose that it is an afferent tract, and that it has its nucleus of origin in one of the peripheral ganglia of the acustic nerve.

Ganglion Isthmi and Isthmo-thalamic Tract. (Fig. 1.)

In what one regards at first glance as cerebellum, but which is just behind it, in the angle it forms with the crista, there lies a large nucleus consisting of six or eight large cells and a number of smaller ones, from which spring two sets of fibres, thick ones and fine ones, which run together, forming a large tract which runs obliquely in an antero-ventral direction across the base of the mesencephalon, crosses the middle line just anterior to the third nerve, and finally breaks up into a plexus round a large mass of cells in the thalamus. This tract appears to be the isthmo-thalamic tract which has been described in birds, reptiles, and the bony fishes. The nucleus forms the ganglion isthmi, which is found practically throughout the vertebrate series. Johnston appears also to have seen this nucleus and tract. He regards the nucleus (the cells of which he describes as spindles) as part of the acustic nucleus, and the fibres as internal arcuate fibres. The above tract is included under the connections of the cerebellum, though it does not form part, because of its close relation to that structure.

The cerebellum of Axolotl is very similar to that of Petromyzon, and the tracts connecting it are also very similar.

As I had only one series of sagittal sections to deal with, and that stained by the Weigert hæmatoxylin method, I was unable to follow out all the tracts. I could not distinguish the cerebellar root of the trigeminal, nor the tegmento-cerebellar tract, neither could I find any trace of the isthmo-thalamic tract, and the cells of the ganglion isthmi could not be differentiated from the others in its neighbourhood; but perhaps when a specimen is stained by the Bielschowsky method, these tracts and cells may be distinguished.

The frontal connections are the same as in Petromyzon, tractus tecto-cerebellaris and tractus cerebello-thalamicus, and their position and course are also very much the same. Caudally the cerebellar root of the acustic nerve is the largest connection, and the fibres are somewhat thick. The only other caudal connection I was able to make out was a tract of fairly

fine fibres coming from the bulb and possibly from the spinal cord, the tractus spino-bulbo-cerebellaris.

The trochlearis runs through the cerebellum very similar to the way it does in Petromyzon.

So the following are the tracts:—

Tractus tecto-cerebellaris.
Tractus cerebello-thalamicus.
Cerebellar root of acusticus.
Tractus spino-bulbo-cerebellaris.

Thus we find in Petromyzon and Axolotl a very similar arrangement to that in Bufo and Rana, and this primitive cerebellum has a similar plan as in the large cerebellum of Scyllium. The vast majority of the fibres entering the cerebellum are the root fibres of the large cranial nerves; and the fibres from the spinal cord, at any rate in mammals, when they can be followed by degeneration methods, are afferent fibres from the sensory roots. These fibres are received by the cerebellum, and it sends out a few small tracts to the thalamus and tegmentum oblongata; therefore I may conclude that even the smallest cerebellum existent is essentially a sensory centre.

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DESCRIPTION OF PLATE XXVII.

Fig. 1.—Sagittal section through the brain of Petromyzon near the middle line, showing course of isthmo-thalamic tract and termination of its fellow of the opposite side anterior to third nerve. The tractus cerebello-thalamicus is seen throughout a large part of its course; the position of the fourth nerve in the cerebellum and the cerebellar root of the acusticus are also shown.

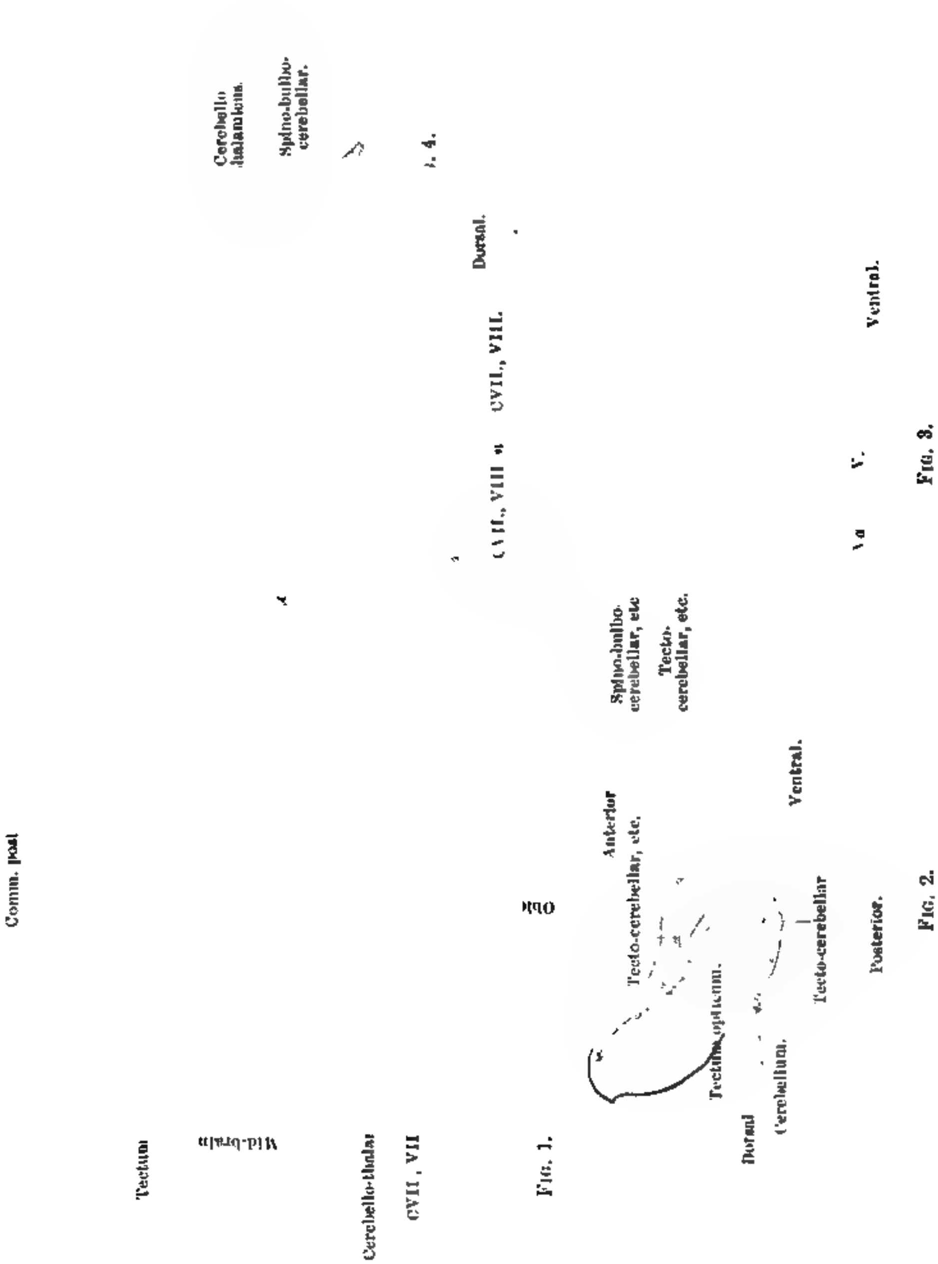

FIG. 1. FIG. 2. FIG. 3.

W. B. CLARK, M.B.

Fig. 2.—Similar to Fig. 1, but nearer the middle line; only tectum opticum and cerebellum shown, and the tractus tecto-cerebellaris.

Fig. 3.—Transverse section of the brain of Petromyzon through the cerebellum and bulb, showing the cerebellar root of the acusticus entering cerebellum, the course of the tegmento-cerebellar tract, and a few fibres of the spino-bulbo-cerebellar tract.

(The above three were stained by the Bielschowsky method.)

Fig. 4.—Sagittal section of the cerebellum of Axolotl stained by the Weigert hæmatoxylin method. This section shows the breaking up of the spino-bulbo-cerebellar tract in the cerebellum, the position of the cerebellar root of the acusticus and of the fourth nerve, and the cerebello-thalamic tract entering the cerebellum.

(Drawings by Fräulein Paula Meyer.)

REMARKS ON THE INNERVATION OF THE DORSUM MANUS, WITH SPECIAL REFERENCE TO CERTAIN RARE ABNORMALITIES. By W. K. HUTTON, M.A., M.B., *Lecturer in Regional Anatomy, the University of Glasgow.* (PLATE XXVIII.).

IN the winter session of 1900–1, while dissecting, for demonstration purposes, the anticubital hollow in the right arm of an adult muscular male subject, I found that the musculo-spiral nerve ended solely as the posterior interosseous trunk, and I thereupon made a careful examination of the nerve supply of the forearm and hand.

The following description of the abnormalities revealed by this investigation is taken from my notes and figures made at the time. These I had laid aside, intending to carry out a more extended research into the innervation of the back of the hand in man and in mammals, but the pressure of other work prevented me from fulfilling, meantime, my original intention in its entirety. I am therefore tempted to publish the case separately, on account of its unusual and interesting character, hoping to be able at some future period to make use of the numerous dissections I have made, and of the conclusions to which I have been led.

I much regret that, at the time when the particular dissection which forms the subject of this paper was made, I was unaware of Brooks' (*Internat. Journ. of Anat. and Physiol.*, vol. v., No. 8, p. 298) recommendations as to methods useful in such work, and dissected the cutaneous nerves of the hand in the usual manner. It is interesting to note that Brooks' suggestion of *inverting* the skin was long ago advocated by Hyrtl in his delightful "*Anatomie des Menschen.*" Speaking of the Pacinian bodies, he says: "Man präparirt sie am besten, wenn man Haut und Fleisch einer Fuss-sohle hart an den Knochen loslöst, und dann von innen her die Nervenstämme gegen die Haut verfolgt."

The distribution of the musculo-cutaneous, external cutaneous of the musculo-spiral and ulnar nerves, was as follows:—

Musculo-cutaneous.—This nerve appeared in the forearm in its normal position, but was rather larger than usual. Lying at the outer side of the tendon of the biceps, it passed beneath the median-cephalic vein, and at once divided into two branches, anterior and posterior. The *posterior*, the smaller of the two, passed outwards and backwards over the supinator

longus, and, coursing downwards, supplied the skin on the radial side of the posterior aspect of the forearm as far as the posterior annular ligament. The *anterior* lay along the ulnar margin of the supinator longus, and reached the radial artery at the insertion of the pronator teres. Superficial to the vessel it passed along with it to the lower end of the radius, in its course giving off numerous small twigs for the supply of the skin over the radial aspect of the front of the forearm.

Two inches above the insertion of the supinator longus, a subdivision of this nerve into anterior and posterior offsets took place, the former division passing to the thenar eminence, the latter winding backwards over the tendons of the supinator longus, the radial extensors of the carpus and the extensor muscles of the thumb. The first of these branches gave off a stout twig which accompanied the superficial volar artery to the palm; it was traced into very close relation with the ramifications of the palmar branch of the median nerve, but did not actually form any connection with this branch. Passing, then, along the radial side of the thumb, and shedding off twigs both to the dorsal and palmar aspects of that digit, the main branch supplied an articular twig to the metacarpophalangeal joint, and finally ended in a brush of filaments at the root of the nail. The ulnar side of the dorsum of the thumb, both sides of the index and middle and the radial side of the ring finger, were supplied by branches from the posterior subdivision of the main anterior branch of the musculo-cutaneous nerve, in the following way (fig. 1, A, Pl. XXVIII.). Two branches were supplied to the thumb, one to the dorsum, the filaments being traceable to the level of the metacarpophalangeal joint, and the other to the ulnar side of the digit. This latter terminated, like the twig to the radial side, in a number of filaments at the root of the nail, and from it a nerve was traced to the sheath of the extensor longus pollicis. The twigs supplied to the index finger were traced as far as the middle of the second phalanx, but there became too slender to follow further; on the middle finger the twigs could be followed as far as the first interphalangeal joint, while the filament to the radial side of the ring finger was exceedingly fine, and could not be traced further than half-way down the first phalanx. The twigs to the index and middle fingers communicated about the middle of the first phalanx with the volar digital branches of the median nerve.

The dorsal aspect of the ring finger, its ulnar side, and the radial side of the little finger, were supplied by an *external cutaneous branch* (fig. 1, B, Pl. XXVIII.) of the musculo-spiral nerve. This latter nerve, after giving off the cutaneous branches to be afterwards described, terminated in the outer part of the antecubital hollow by supplying the supinator longus and the long extensor of the carpus, ultimately piercing the supinator brevis as the

posterior interosseous nerve, whose relations on the extensor aspect of the forearm were normal in every way. Of a *radial nerve* proper (ramus superficialis, n. rad.) there was not a trace.

Between the insertion of the deltoid and the outer condyle of the humerus, *four* cutaneous branches became superficial between the brachialis anticus and outer head of the triceps. Of these four, two were small. Arising higher up than the others, they coursed downwards, supplying the skin on the outer side of the arm as far as the elbow joint, and one of them, passing in front of the epicondyle, was traced about half-way down the forearm over the radial extensors of the carpus. The lower two branches took up a position between the olecranon and the outer condyle, and on the back of the forearm were, relatively, radial and ulnar. Both gave many twigs for the supply of the skin over the back of the forearm, but while the radial branch terminated in filaments over the posterior surface of the metacarpal region, the ulnar, coursing downwards over the back of the hand, broke up into slender branches for the supply of the ring and little fingers (fig. 1, B, Pl. XXVIII.). One or two of the stoutest filaments could be followed as far as the bases of the second phalanges of both these digits.

The *ulnar nerve* supplied its usual muscular branches and palmar offset, but its dorsal twig (fig. 1, C, Pl. XXVIII.) was smaller than usual, and after furnishing carpal articular branches and twigs to the ulnar side of the hypothenar eminence, this branch ended by distributing filaments to the skin on the ulnar side of the dorsum of the little finger as far as the nail. No twig could be traced to the radial side of that digit, or to the ring finger.

In the case above recorded, several abnormalities in the nervous supply of the back of the hand appear together, some of a rarity much greater than others; and although examples, somewhat similar, of each individual departure from the normal have previously received the attention of anatomists, their simultaneous occurrence in one dissection is, so far as I am aware, unique.

The relative amount of skin area on the back of the hand, supplied usually by the radial and dorsal branch of the ulnar nerve, is of variable extent, as the researches of Brooks (*Internat. Journ. Anat. and Physiol.*, vol. v., No. 8, p. 297), Hedon (same Journal, vol. vi., Nos. 4 and 5, p. 141), and Zander (*Anat. Anzeiger*, Dec. 1889, p. 751) show, with very full detail, and all of these observers agree in considering that a portion of the general area, roughly median in position, receives a supply derived from both nerves, either by means of inter-crossing fibres or by anastomoses between the nerves. The three papers mentioned deal so fully with this point that further elaboration seems needless, but it is of interest to note in this

connection, that part at least of this debatable area is supplied in the present case by a totally distinct nerve, the external cutaneous of the musculo-spiral, a trunk which normally takes but a subsidiary part in the innervation of the hand. Anastomosis I find to be common in the Simiidæ, and fig. 3, Pl. XXVIII., from a Cercopithecus, represents, according to my investigations, a usual arrangement. It will be seen that by means of three anastomoses the ulnar and radial sides of the third and fourth fingers, respectively, receive a combined nerve supply, and that moreover an almost plexiform arrangement of the filaments obtains throughout the course of each nerve separately. The drawing was taken from a dissection, under water, of the nerves on the *inverted* skin.

To return to variations not rare in the innervation of the human hand, it is found that the area of skin supplied by the dorsal branch of the ulnar nerve is seldom increased—diminished extent, as in the present case, being the commoner condition.

A notable example of the opposite state of matters, associated with absence of the radial nerve, is put on record by Hepburn (*Journ. Anat.*, xxi., p. 511). So far as I am aware, this case, and my own, afford the only recorded examples of absence of the radial nerve, and the abnormality must therefore be of the greatest rarity. In Hepburn's example, the dorsal branch of the ulnar supplied an enormously augmented extent of skin. All the fingers were supplied by this nerve, while the musculo-cutaneous was distributed to both sides of the thumb and to the thenar eminence, and sent also a fine twig to the base of the index finger.

The external cutaneous branch of the musculo-spiral did not reach the back of the hand.

For the purposes of comparison, I append to this note two sketches (Pl. XXVIII.), fig. 1 showing the condition met with by myself and taken from the actual dissection at the time, while fig. 2 is an ideal representation, to the same scale, of Hepburn's case imagined from the printed description. If now these sketches be compared with Hedon's scheme (*Quain's Text-Book*, vol. iii., pt. ii., fig. 201, B, p. 306) of the normal nerve distribution, it will at once be noted that my own case and Hepburn's occupy positions at the extremes of abnormality. Both record total absence of the radial nerve, whose place is in each case taken by the musculo-cutaneous; but while in Hepburn's example the distribution of the ulnar nerve is, as regards the back of the hand, almost total, in mine its dorsal branch is reduced practically to the minimum.

Increase in the normal area of supply of the musculo-cutaneous has been occasionally observed. " H. Virchow and Th. Kölliker describe a case in which it gave the dorsal digital nerves to both sides of the ring and to

the radial side of the little finger" (*Quain's Text-Book*, vol. iii., pt. ii., p. 299), and Hedon (*loc. cit.*) in his figure indicates that the skin over the first interosseous space may be supplied by this nerve normally. In a case of congenital shortening of the radius and ulna, with total ankylosis of these bones to the humerus, associated with imperfect development of the hand, I found the skin over the back of the thumb and dorsum of the diminutive hand supplied by nerve filaments derived from a union of the musculo-cutaneous nerve and the lower of the two external cutaneous branches of the musculo-spiral; but such a marked increase in the area of distribution of the musculo-cutaneous as obtains in the present case wholly eclipses this, and apparently has hitherto not been observed.

As regards the termination of the external cutaneous branches of the musculo-spiral, it is to be remarked that Hedon (*loc. cit.*) considers that both may normally be traced to the wrist, and Gegenbaur (*Traité d'Anatomie Humaine*, p. 1056) says: "W. Gruber a vu ce rameau cutané externe s'étendre jusqu'aux derniers doigts et remplacer les nerfs collatéraux dorsaux du n. cubital." In the case I record, the normal extent is very markedly increased, fully one-third of the skin on the back of the hand being supplied by this nerve.

Finally, apart from its evident great rarity, such a strongly accentuated departure from the normal, as the one above described, gains an added interest from the following consideration: John Goodsir, in his short but suggestive paper, "On the Morphological Constitution of Limbs" (*Anatomical Memoirs*, vol. ii., p. 198, *et seq.*), was the first to point out the serial metamerism in a direction pre- and postaxial of the upper limb; and as regards the nervous segmentation expressed himself as follows: "... but it appears to be extremely probable that in the mammalia at least five spinal nerves transmit filaments to the five distal divisions of the limbs. It would appear too that, notwithstanding their plexiform arrangement at the attached end of the limb, *the greater number of the filaments of each nerve reach their own morphological district at the distal part of the limb. The radial and the ulnar nerves are formed principally by the upper and lower roots of the human brachial plexus*—that is, from the nerves of the upper and lower primordial segments with which the embryo limb was connected, and from which it derived its various elements." (The italics are mine.) The principle enunciated in the lines which I have italicised has received a more general expression by Herringham in his paper on the human brachial plexus (*Proc. Roy. Soc.*, xli., 1886), in which he postulates that "of two spots on the skin, that which is nearer the preaxial border tends to be supplied by the higher nerve." Now, in the normal distribution of the nerves to the back of the hand, that portion nearer to the preaxial

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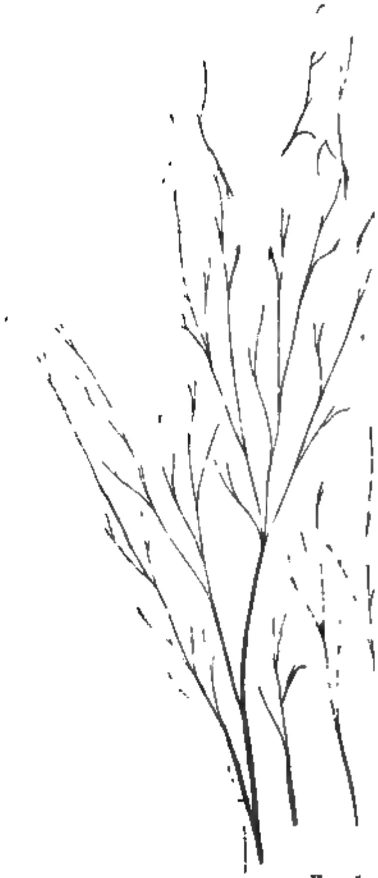

FIG. 1.

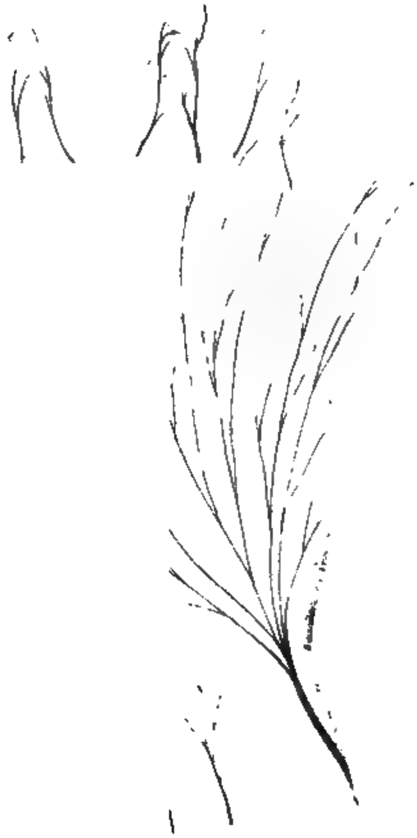

FIG. 2.

FIG. 3.

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side of the limb is supplied by the radial nerve, that near the postaxial by the ulnar, the whole area being as a consequence supplied from pre- to postaxial borders by filaments from the VIth, VIIth, and VIIIth cervical nerves in that order. In the abnormality recorded, in spite of the absence of the radial nerve and the intrusion of the external cutaneous branch of the musculo-spiral, the same generalisation holds good; for the preaxial side of the hand is supplied by the musculo-cutaneous, with filaments derived from the Vth and VIth nerves, the central portion by the external cutaneous of the musculo-spiral, with fibres from the VIth and VIIth, and the postaxial border, normally, by fibres arising from the VIIIth cervical.

In short, in place of the normal order VI., VII., and VIII., we obtain V., VI., VII., and VIII., a higher nerve being included at the preaxial border, and the series remaining unbroken.

EXPLANATION OF THE PLATE.

Fig. 1.—Distribution of the nerves on the back of the hand in a case of absence of the radial nerve. Musculo-cutaneous and the volar branches of the median nerve, blue; external cutaneous of musculo-spiral, green; dorsal branch of the ulnar nerve, red. For reference letters see text.

Fig. 2.—Distribution in Hepburn's case of absence of the radial, showing enormous increase in the area supplied by the dorsal branch of the ulnar. (Same colouring.)

Fig. 3.—Normal scheme of innervation in a Cercopithecus. Radial nerve, blue; dorsal branch of the ulnar, red; combined nerve supply, black. AA, anastomoses in the radial nerve; B, anastomosis in the ulnar nerve; C, anastomosis forming the combined nerve supply. (From a dissection under water.)

A CASE OF ECTOPIA VISCERUM, ASSOCIATED WITH SPINA BIFIDA AND OTHER ABNORMALITIES.[1] By Dr E. Emrys-Roberts and Professor A. Melville Paterson, *Liverpool.*

The subject of this memoir is a full-term fœtus, born dead, and we are indebted to Dr E. T. Davies of Liverpool for the opportunity of describing a somewhat rare condition.

The father of the child died, at the age of thirty-two, two months before its birth, of acute phthisis, accelerated by alcoholism. The mother (iv. para) is a healthy woman aged thirty years. Her three preceding children were healthy and normal in every respect. There was no noticeable feature about the pregnancy or labour. On the arrival of the accoucheur, the membranes had already ruptured, and the viscera and a hand were presenting. During strong expulsive pains delivery was accomplished, the dead fœtus being expelled with some force. The viscera and trunk came first, then the lower extremities, which were acutely flexed on the spine, followed by the shoulders and head, and lastly, the membranes and placenta.

External Appearances. (Fig. 1.)

The body of the child measures 9 inches from head to perineum. The head and limbs are well formed, but the trunk is in a position of acute opisthotonos, the legs embracing the scalp posteriorly. A spina bifida in the lumbo-sacral region forms a fluctuating swelling the size of a hen's egg. In the middle line of the perineum is a blind proctodœal depression; on the left side of the thigh, on the level of this depression, is a small pedunculated papilla, and on the right thigh there is a corresponding sessile elevation (fig. 3). The amnion is attached to the skin along an oval margin extending from the thorax to the lower part of the abdomen, and forms a large sac completed by its attachment to the placenta, and containing the abdominal viscera, the pericardium and heart, and the left lung.

Placenta and Membranes. (Figs. 1 and 2.)

The placenta is discoidal and measures 6×5 inches. Its fœtal surface is covered by the amnion, which at the margin of the placenta becomes con-

[1] Read before the Anatomical Society, January 19, 1906.

tinuous with the other fœtal membranes and lines the amniotic sac. The amnion is reflected off the placenta near its centre, at the attachment of the umbilical vessels, and becomes the wall of the ectopic sac, attached to the body wall of the fœtus along an oval line already referred to. The

FIG. 1.—Photograph of the specimen as received.

umbilical vessels (one artery and one vein) are carried from the fœtus to the placenta in the hinder part of the wall of this sac. The placental end of the sac is adherent at several places to the amnion covering the fœtal surface of the placenta by means of delicate septal bands.

There are thus two distinct and separate cavities: (1) the cœlomic cavity, the pleuro-peritoneal cavity of the fœtus, and the ectopic sac, which represents the persistence of the extra-embryonic cœlom; and (2) the

FIG. 2.—Diagrammatic reproduction of the specimen representing a sagittal section through the trunk and ectopic cavity. The dotted line (* *) represents the limit of the abdominal cavity.

A, spina bifida; B, pericardium; C, left lung; D, stomach; E, mesentery; F, small intestine; G, cæcal pouch and left appendage; H, liver; J, placenta; K, umbilical vessels; L, fibrous cord connecting the gut to the coccyx and to the posterior end of the spinal cord; M, proctodæal recess; N, cloacal papilla; O, termination of intestine; P, bladder-like dilatation; Q, border of internal cloaca; R, external cloacal opening; S, cloacal cavity and opening of bladder-like dilatation.

cavity of the amnion itself, in which the fœtus and the ectopic sac are contained.

External cloaca.—Between the two cavities is a natural opening or external cloaca (fig. 3). This is a median longitudinal fissure five-eighths of an inch in length, which occurs chiefly in the amnion, but also encroaches

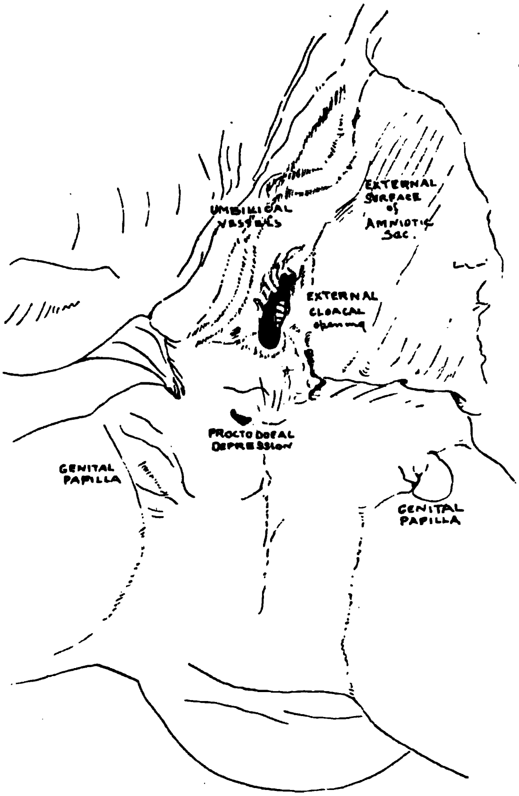

FIG. 3.—Drawing of the perineal region, to show the proctodœum, external cloaca, and genital papillæ.

on to the skin for about a quarter of an inch. It lies three-quarters of an inch in front of the proctodœal depression. It not only forms a natural communication between the amniotic cavity and the cœlom, but, as will be described later, it is also in relation to the opening of the *internal cloaca.*

Abdominal wall.—The two halves of the abdominal wall, widely separated from one another and forming on each side the fœtal attachment of the ectopic sac, consist of the following muscles and their aponeuroses:

(1) obliquus externus, with an attachment above to the fifth, sixth, and seventh ribs and below by a membranous band to the hip-bone: possessing a well-developed aponeurosis, which serves for the attachment of the serratus magnus, pectoralis major, pyramidalis and sternalis; (2) obliquus internus, inserted by an aponeurosis into the border of the eighth costal cartilage, and into the skin-amnion junction; (3) transversalis, arising from the eighth, ninth, and tenth costal cartilages and inserted into the skin-amnion junction;

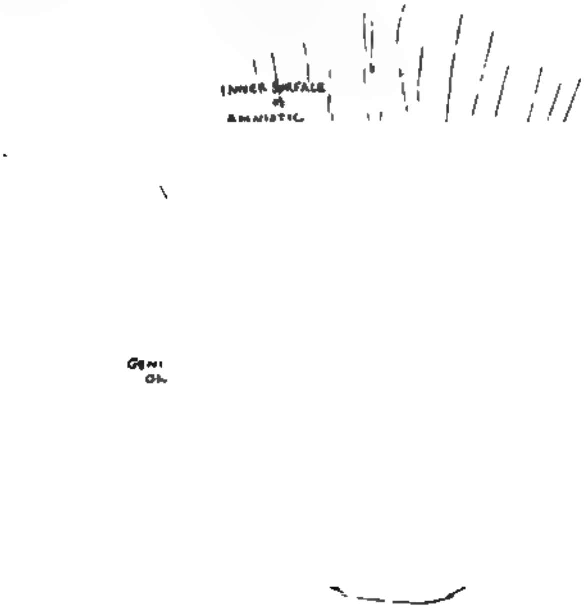

Fig. 4.—Drawing to show the deep surface of the external cloaca and the termination of the gut (without dissection).

(4) rectus abdominis, narrow and rounded, with an upper attachment to the third costal cartilage, and a lower attachment by a long narrow tendon into the pubis; (5) pyramidalis, a long narrow muscle lying superficial to the rectus abdominis in its lower third; (6) sternalis, a well-developed muscle on both sides in the same plane as the pyramidalis, and superficial to the pectoralis major and rectus abdominis.

The Ectopic Sac and its Contents.

The ectopic sac was ruptured at the time of delivery, but its wall is nevertheless complete. The deep surface of the external cloaca is seen to possess a puckered margin (fig. 4), which is joined on each side by the

edges of the internal cloaca. This is a narrow slit opening from the cloaca into the cœlom. It is almost completely filled up by the projection into it of a prominent papilla. A probe passed through the opening enters in the middle line into the end of the intestinal canal, while on either side of the papilla into the cavity of a thick-walled muscular sac which on dissection resembles a bladder in structure. The connection of the margins of the external cloaca and internal cloaca thus allows a probe, passed through the external cloaca, to pass either into the cœlom or through the cœlom into the internal cloacal opening.

The interior of the ectopic sac is lined by a serous covering continuous and identical with the peritoneum. In the wall of the sac, as already noted, the right umbilical artery and vein course to the placenta. There is no trace of left umbilical vessels. The right artery passes an eighth of an inch from the right side of the external cloaca. The vein is half an inch further out.

The interior of the sac includes the peritoneal cavity, and, on account of a deficiency of the left half of the diaphragm, the rudimentary left pleural sac. On the left side the pleuro-peritoneum is prolonged upwards within the costal margin for only a short distance. It forms, in addition, a small blind pouch or further prolongation at the root of the left lung. The right pleural sac is completely isolated, and will be described in the account of the thorax.

The contents of the ectopic sac and pleuro-peritoneal cavity are: the lower two-thirds of the pericardium and heart, the left lung, stomach, spleen, liver, and intestines. Attached to the posterior abdominal wall are the kidneys, genital glands, pancreas, duodenum, blood-vessels, and the structures involved in forming the cloacal cavity.

THE DIAPHRAGM.

The right half of the diaphragm forms a continuous, fibro-muscular partition separating the right pleural cavity from the abdominal cavity. It is pierced by the inferior vena cava, and is covered by peritoneum on its abdominal aspect. Its muscular fibres arise from three peripheral origins: (1) anteriorly and on the right side, from the costal margin, (2) and (3) posteriorly from the vertebral column by two bundles of muscular fibres separated from one another by a plexiform mass of sympathetic nerves and lymphatics which lie on the right side of the aorta. It is supplied by the right phrenic nerve.

The left half of the diaphragm is represented by a muscular bundle which arises from the under surface of the left ninth costal cartilage, and passes

between, first, the left side of the œsophagus and left lung, and then between the liver and the pericardium on the one hand and the stomach on the other hand, to blend with the connective tissue of the small omentum and the hilum of the liver. It is supplied by the left phrenic nerve.

Peritoneal Folds.

The liver possesses a well-marked falcifum ligament (in the free edge of which the right umbilical vein courses), and distinct right and left lateral ligaments connecting it to the diaphragm.

The stomach is connected to the liver by a small omentum. The great omentum extends from its greater curvature and blends below with the root of the mesentery proper, which encloses the coils of the small intestine. A short septal band of peritoneum attaches the border of the fundus of the stomach to the wall of the sac between the left lung and suprarenal capsule.

The spleen is covered entirely by peritoneum, and is attached to the fundus of the stomach by a gastro-splenic omentum and to the posterior abdominal wall by a lieno-renal ligament.

The lesser sac is well developed, and communicates with the greater sac by means of a large foramen of Winslow.

Abdominal Viscera.

The œsophagus enters the abdomen between the two halves of the diaphragm.

The stomach is well developed, and possesses a distinct pylorus. The duodenum is normal in position and curvature and is of large calibre.

The jejunum and ileum together measure 26 inches in length. For 22 inches the calibre of the tube is uniform. It then dilates, ultimately narrowing again at its termination. The interior of the tube in its whole length is provided with well-marked valvulæ conniventes.

Termination of the small intestine.—Half an inch from the internal cloaca the small intestine ends in an enormously dilated cæcal pouch, measuring 2 by 1½ inches (fig. 4). It is slightly sacculated on its exterior, and is situated on the right side of the lower part of the abdominal cavity. Behind it is a large ileo-cæcal pouch of peritoneum, bounded by a fold of peritoneum by which the cæcal pouch is connected with the mesentery. On each side of the junction of the small intestine with the cæcal pouch is a small, sacculated and curved, appendix. This cæcal pouch communicates by a narrow neck with the upper end of the cavity of the cloaca.

Attached to its dorsal wall is a thick fibrous cord partially enveloped in muscular fibres, which is directed dorsally, narrowing as it goes, to be attached chiefly to the tip of the coccyx. Behind the coccyx it is continuous with another cord—a prolongation from the sac of the spina bifida.

The first-named cord represents a post-anal gut. Along with the prolongation from the spina bifida the structure constitutes the remains of the neurenteric canal. The interior of the cæcal pouch is lined by a mucous membrane, which presents numerous fine rugosities.

The liver is large and irregular. Its parietal surface, convex and kidney-shaped, is wholly covered by peritoneum, and is in contact with the abdominal wall, right half of the diaphragm, and pericardium. It possesses no peritoneal folds.

The visceral surface of the liver presents numerous fissures. The fissure for the gall-bladder extends from the anterior border of the liver to the hilum. To the left of this is a superficial fissure, representing the anterior portion of the longitudinal fissure and the position of the (absent) left umbilical vein. The hilum and its vessels and ducts are normal. The gall-bladder is small. The fissure for the ductus venosus is a deep fissure. It attaches part of the small omentum, and receives the muscular fibres of the rudimentary left half of the diaphragm. The fissure for the inferior vena cava is also deep. It lies behind the spigelian lobe, and has three peritoneal folds connected with it: the right and left lateral ligaments, and the falcifum ligament. A deep notch occurs on the posterior border of the liver for the entrance of the right umbilical vein. The several lobes of the liver can be readily made out: the spigelian lobe is especially prominent, projecting for over an inch into the lesser sac, behind the stomach and duodenum.

The portal vein is normal. On entering the hilum it forms a large sinus, and divides into right and left branches. The left branch is in continuity with the ductus venosus, which connects it to the inferior vena cava in the usual way. As already said, there is no trace of a left umbilical vein. The right branch of the portal vein becomes embedded in the liver, where it is joined by the right umbilical vein. This vein, after coursing over the posterior abdominal wall, enters the free edge of the falcifum ligament; passing over the right kidney, it enters the liver, and after a course of half an inch opens into the right branch of the portal vein.

The spleen and pancreas are normal in position and relations.

The right kidney and suprarenal capsule lie on the posterior abdominal wall, covered over by peritoneum. Both are related to the liver, falcifum ligament, duodenum, and the cæcum. The hilum of the kidney occupies its

anterior surface. The ureter descends vertically to terminate in a muscular cul-de-sac, which communicates with the cavity of the cloaca.

The left kidney and suprarenal capsule are separated by peritoneum from the spleen, left lung, and the lesser sac of the peritoneum. The lieno-renal ligament is attached to the kidney. The ureter has an origin, course, and termination just as on the right side. The renal vessels will be described later.

The genital glands are similar on the two sides: each is attached by a peritoneal fold to the lower end of the kidney. The gland is ovoid in shape, laterally compressed, and about half an inch in length. It is divisible into two parts: a basal part, soft and yellowish in colour and covered by glistening peritoneum, and a smaller portion, separated by a marginal fissure, brownish in colour, rough and wrinkled.

The genital duct has a different course and termination on the two sides. The right duct is represented by a fibrous cord which passes downwards and outwards to the groin. It pierces the tissues of the abdominal wall, and merges with a strong band of fascia attached to the pubis (? Poupart's ligament). The left duct is pervious. It passes downwards over and internal to the left ureter, and ends by joining a thick, glandular mass (? prostate) placed behind the cloacal chamber. Each genital gland is supplied by branches from the renal vessels.

Cloaca.—Below the termination of the intestine, with its cæcal dilatation and bilateral appendices, a slit-like opening about half an inch in length occurs in the ventral wall of the cloacal cavity, which allows of a communication with the cœlom. This is the *internal cloacal orifice.* Its margins are continuous above with the anterior margin of the opening of the gut, and below with the sides of the *external cloacal orifice* (fig. 2). The opening is almost completely filled up by the projection into it of a *cloacal papilla* which projects from the dorsal wall of the cloacal chamber and divides it into two lateral parts. The papilla possesses fræna, superior and inferior. The superior frænum passes upwards to the left side of the opening of the gut: the inferior frænum descends in the middle line to the orifice of the cloaca. The lateral walls of the cloacal chamber are thick and muscular, and form on each side a small, almost spherical, *bladder-like sac* which opens into the cavity of the cloaca on each side of the papilla by a wide, slit-like mouth. Each of these sacs is covered over anteriorly by peritoneum, and each receives at its upper pole the termination of the ureter.

Behind the dorsal wall of the cloacal chamber, above the side of the cloacal papilla and below the attachment of the post-anal gut, and between the urinary diverticula, is a solid median glandular mass, resembling the

prostate gland. It intervenes between the post-anal gut and the proctodœal diverticulum, and, as already noted, receives the termination of the left genital duct.

The cloacal papilla attached to the dorsal wall of the cloacal chamber has a clubbed and fissured extremity which projects through the internal cloacal opening. On dissection the papilla is found to be composed of a dense mass of fibrous tissue, and it contains in its centre a gradually narrowing fibrous cord, easily detachable from its surroundings, and traceable into continuity with a narrow tube which finally opens on the surface of the perineum as the proctodœal depression.

The perineum.—The pubic bones are widely separated from one another. The two ischia are connected together by a strong, fibro-muscular septum, which separates the spina bifida sac from the ischio-rectal fossæ. This sheet is pierced in the middle line by a fibrous cord which extends from the spina bifida sac to the tip of the coccyx. The proctodœal depression lies between the two ischio-rectal fossæ. It is half an inch in depth and forms a cylindrical tube continued into the narrowing fibrous cord already described as penetrating and ending in the substance of the cloacal papilla. On each side is the levator ani muscle, behind which is the coccygeus. The pudic vessels and nerves traverse the outer wall of the fossa. In addition, a fibrous band comparable to the triangular ligament and muscular bundles corresponding to the transversus perinei and compressor urethræ can be made out, in front of the proctodœum, between the widely separated pubic bones.

Abdominal Vessels.

The abdominal aorta (fig. 5) is a short vessel. At the level of the kidneys it gives off several visceral branches which divide to supply the kidneys, suprarenal capsules, genital glands, and spleen. Other arteries which were cut entered the mesentery to supply the gut. On the left side a slender artery arises which soon divides into two: one branch was cut; the other is the pudic artery, which courses along the left side of the sacrum, supplies the perineum, and terminates in the cloacal papilla. On the right side also the pudic artery is a direct branch of the aorta.

The external iliac arteries arise differently on the two sides, The left artery arises from the common trunk from which the renal, genital, suprarenal, and splenic arteries arise; the right artery arises from the aorta, just above the origin of the pudic artery. These two vessels supply subordinate branches to the buttocks, and proceed onwards to the lower limbs, to form the femoral arteries. The internal iliac arteries arise directly from

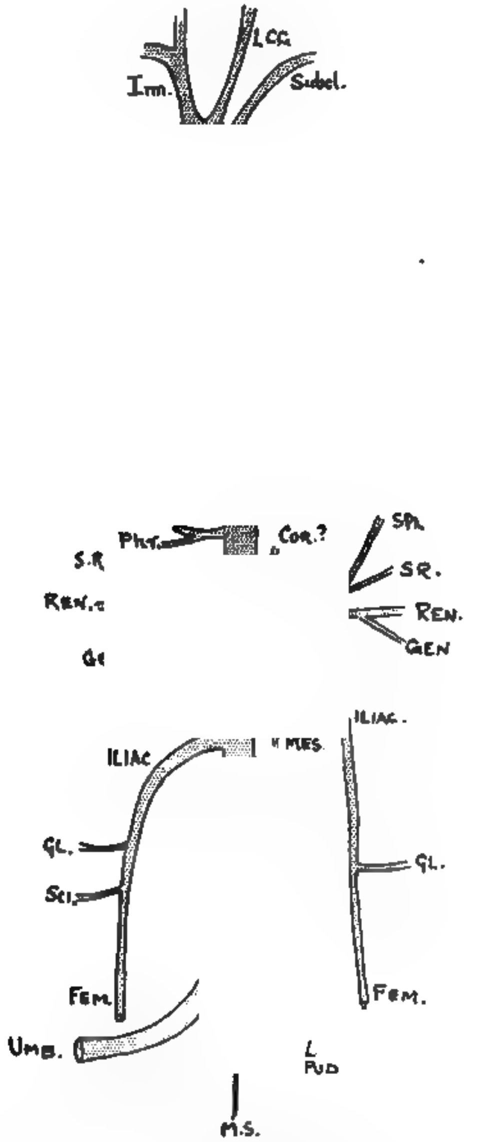

Fig. 5.—Diagrammatic representation of the aorta, with its chief abdominal branches.

Inn., innominate artery; L.C.C., left common carotid; Subcl., subclavian; Hep.? hepatic; Phr., inferior phrenic, Cor.? coronary; Spl., splenic; S.R., suprarenal; Ren., renal; Gen., to genital gland; Iliac, external iliac artery; Gl., gluteal; Sci., sciatic; Fem., femoral; L. Pud., left pudic; M.S., middle sacral; Umb., right umbilical artery

the aorta, and are distributed to the pelvic viscera. The aorta, finally, after giving off a minute middle sacral artery, terminates as the *right umbilical artery*, which, passing behind the end of the intestine, is conducted to the placenta in the wall of the ectopic sac.

The inferior vena cava is formed between the kidneys by the union of the renal veins with several veins ascending from the pelvis. Lying on the surface of the right kidney, it ascends between the right and spigelian lobes of the liver to the diaphragm, the right half of which it pierces.

There is a well-marked solar plexus in relation to the abdominal aorta, from which branches supply the adjacent viscera.

SPINA BIFIDA. (Figs. 2 and 6.)

The spina bifida forms a tumour as large as a hen's egg in the lumbo-sacral region of the spinal column.

On removing the skin covering the tumour, a thick-walled muscular bag is disclosed, formed by the gluteal muscles fused together and extending over both buttocks, and pinned down laterally to the hip-bones and femora by muscular and tendinous fibres corresponding to the attachments of the glutei. This bag is connected to the spinal column above, and is limited in the middle line below by deep transverse muscular fibres.

The removal of this bag from its attachments discloses the sac of the spina bifida, and on each side the hip-joint with the sciatic and other nerves coursing through the buttock.

The sac of the spina bifida is spherical, and measures two inches in length by one and a half inches in width. As it emerges from the aperture formed by the deficient spinal laminæ of the last thoracic, lumbar, and sacral vertebræ, it is seen to be continuous with the dura mater covering the spinal cord. The posterior pole of the sac is continued onwards in the middle line near its basal attachment as a thick fibrous cord half an inch in length, which is attached to the tip of the coccyx, and is continuous with the cord representing the post-anal gut (neurenteric canal): the lower spinal nerves pierce the basal portion of the sac.

On opening this sac of dura mater, it is found to contain a second large sac formed by a tough yellow layer of fibrous tissue, smooth and glistening on its inner surface and filled with a slightly turbid fluid (fig. 2). This is the distended central canal of the spinal cord, clothed by pia mater. On the left side it is adherent to the arachnoid and dura mater, which have to be stripped off to expose it. On the right side it is almost entirely free, so that there is a large subarachnoid space. In two places on the right side the

arachnoid and dura mater are separated so as to constitute two separate subdural spaces filled with fluid.

In the floor of this sac are two openings occupying the middle line, and half an inch apart. The upper one is a narrow channel which communi-

FIG. 6.—Showing the sac of the spina bifida emerging from the spinal canal (S.B.), the fusion of the ribs on the left side, the flexion of the vertebral column, and the projection of the pericardium and heart below the costal arch.

cates with the central canal of the cord. The lower one forms a tubular prolongation half an inch in depth, continued into the fibrous cord above mentioned, which is attached to the coccyx.

The roots of the lower spinal nerves are attached to the base of this sac in three situations: (1) to the sides of the upward prolongation; (2) to the floor of the sac; (3) the last nerve, which is very minute, arises by two roots from the lower tubular prolongation close to its termination. The

dorsal and ventral roots of the nerves remain separate until they have pierced the dura matral sac.

The spinal cord itself ends in relation to the last complete neural arch, the laminæ of the last thoracic vertebræ being, as already noted, deficient, to allow of the passage of the neck of the sac.

Hydrocephalus.—The external appearances of the skull gave rise to no suspicion of the presence of any hydrocephalus, and in opening the cranium there was no accumulation of fluid in the cavity of the dura mater.

There were some adhesions (1) in the posterior fossa where the cerebellum and medulla were adherent to the tentorium cerebelli and the dura mater lining the posterior fossa, and (2) between the falx major and the corpus callosum.

The cerebral hemispheres were richly convoluted, but the separating sulci were shallow. The walls of the hemispheres were extremely thin and the cavities of the lateral ventricles were distended by a quantity of fluid. The brain was so soft and friable that a more detailed examination was unfortunately impossible.

Vertebral Column, Ribs, and Sternum: Thoracic Cavity.

In consequence of the ectopia and the spina bifida, the vertebral column, ribs, and sternum are subject to remarkable abnormalities.

1. *Vertebral column.*—The irregularities in structure are confined to the thoracic, lumbar, and sacro-coccygeal regions (figs. 6, 7, 8).

The cervical vertebræ are normal in all respects.

The thoracic vertebræ present a remarkable series of abnormalities.

This part of the column is markedly concave in the forward direction, particularly in its lower part (fig. 2), which results in peculiarities in the component vertebræ and also in the ribs of the right side.

The bodies, pedicles, and laminæ of the thoracic vertebræ are very irregular, and do not agree together in number or arrangement (fig. 7). The bodies of the first three vertebræ are separate from one another, and each has a large median centre of ossification. The bodies of the remaining thoracic vertebræ (except the last) are represented by an elongated cylindrical mass of cartilage in which are embedded three centres of ossification. The intermediate centre is the largest, and appears to represent the fusion of two or more osseous centres. The body of the last thoracic vertebra is small and wedge-shaped, and does not extend as far as the right border of the vertebral column. It possesses a separate centre of ossification.

The arches of the thoracic vertebræ are extremely irregular, especially on the right side. The pedicles of the vertebræ number eleven on the left

side, ten on the right side. (On the right side the first lumbar vertebra possesses a double pedicle perforated by a foramen.) On the left side these

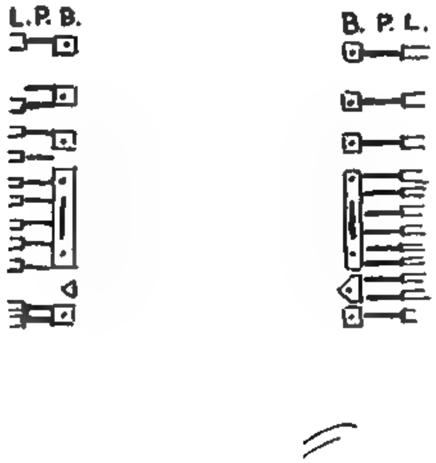

FIG. 7.—Front view of the vertebral column, showing the fusion and irregularity of the vertebræ. On each side a reconstruction is given, showing the relations of the respective pedicles (P) to the laminæ (L) and the bodies (B)

pedicles correspond to a similar number of transverse processes, ribs and laminæ. The laminæ alone are abnormal, in their dorsal connections. The third and ninth laminæ fail to join the laminæ of the opposite side, and the eleventh lamina is deficient at the level of the neck of the sac of the

spina bifida (fig. 8). On the right side the arches are more irregular, and the pedicles (and transverse processes) do not correspond to either bodies or laminæ. Not only is the eleventh pedicle incorporated with the first lumbar vertebra, but the others are abnormal also. The body of the second thoracic vertebra bears two pedicles, of which the first is rudimentary and is connected with no lamina. The fused mass below the third thoracic vertebra carries six pedicles, each associated with a separate lamina, of which the last is deficient in relation to the neck of the sac of the spina bifida. In other words, the thoracic vertebræ are doubtful in number; there are eleven pedicles on each side (the eleventh on the right side being incorporated with the first lumbar vertebra); there are eleven laminæ on the left side and nine on the right side, the last in each case being deficient opposite the emergence of the spina bifida; and there are eleven ribs on each side, crowded together alongside the compressed and curved column, and corresponding not to the bodies, but to the pedicles of the series of thoracic vertebræ.

The lumbo-sacral portion of the vertebral column presents a remarkable convexity in a forward direction, most prominent in the lumbar region.

The lumbar vertebræ are four in number, each with a separate body possessing a large median centre of ossification, separate transverse processes, and imperfect laminæ. The pedicle and transverse process of the first lumbar vertebra on the right side is double, and is perforated by a foramen. The upper portion represents the pedicle and transverse process of the last thoracic vertebra. The imperfect laminæ of these vertebræ help to bound the neck of the sac of the spina bifida.

The sacrum and coccyx are fused together in one cartilaginous mass. There are six irregular centres of ossification, and the end of the coccyx is hooked forwards and to the right side. The anterior surface is slightly convex, and the iliac bones articulate with the first three sacral vertebræ. The neural arches of all the vertebræ are deficient, and with the last thoracic and the lumbar laminæ help to bound the space containing the spina bifida.

The curvature of the vertebral column is one of the most remarkable features of this region. Its causation is obscure. It is more than doubtful if it is due to the persistence of the embryonic curve described by His (11) and others. It is probably ascribable to the weakness of the spinal column produced by (1) the deficiency of the neural arches associated with the occurrence of the spina bifida, and (2) the deficiency of the abdominal wall and the rotation of the lower limbs due to the ectopia. It is the direct cause of a remarkable disposition of the thoracic wall next to be described.

Thoracic and abdominal walls.—There are marked abnormalities on

the walls of the thorax and abdomen, and the diaphragm is deficient on the left side, so that the left pleural sac is practically absent, and the left lung is abdominal in position.

Thorax, ribs, and sternum.—The sternum is rudimentary: the ribs, eleven in number on each side, present a remarkable flattening on the left side on account of the collapse of the left wall of the thorax (fig. 10). On the right side (figs. 6, 9), where there are a separate pleura and lung, the ribs have a well-rounded curve, but are compressed and fused together (in consequence of the bending of the vertebral column).

The vertebral connections of the ribs correspond to the pedicles and not

FIG. 8.—The laminæ of the thoracic vertebræ, with their rib connections. The neck of the spina bifida (S.B.) is seen emerging from the spinal canal, and sloping backwards between the ilia.

FIG. 9.—Representing the sternum and costal cartilages, with the fused ribs of the right side.

to the bodies of the thoracic vertebræ. Their heads are crowded together at the vertebral articulations, especially in relation to the fused thoracic vertebræ.

The shafts of the ribs and the connections of their distal extremities present a marked contrast on the two sides. On the left side (fig. 10) the ribs are free from one another and are movable. The costal cartilage of the first rib is elongated, and fused with the side of the sternum just below the clavicular facet. The costal cartilages of the second and third ribs are shorter, and are attached to the side of the sternum by means of intervening fibrous laminæ. The cartilages of the succeeding four ribs (fourth to seventh) are fused together to form an elongated bar of cartilage, which helps to form the left side of the costal arch, and is continuous with the left side of the lower end of the sternum. The cartilages of the eighth and ninth ribs are

successively attached by fibrous union to the costal cartilages of the preceding ribs, and complete the costal arch on the left side. The tenth rib possesses a rounded costal cartilage which projects freely among the muscles of the abdominal wall, and that of the last rib descends almost vertically to articulate with the iliac crest.

On the right side (figs. 6, 9) the first and second ribs are free and have connections similar to those on the left side, the costal cartilage of the first being fused with the side of the sternum, and that of the second being attached by means of a fibrous lamina. The remaining ribs are free from one another at their vertebral ends, and their heads and shafts can be

FIG. 10.—Representing the disposition of the ribs in the left side of the thorax.

readily made out as far as the angles of the ribs. Further forwards they are united together by bony union, so as to form a broad osseous plate in which it is scarcely possible to determine exactly the individual ribs. Certain of them are separated to some extent by slight or well-marked grooves. The irregularity of their distal extremities and of their sternal connections adds still further to the difficulty of tracing them in their entire length. The third rib becomes free from the plate, at its sternal end, and is attached by a well-marked costal cartilage to the border of the sternum, a fibrous lamina intervening. Projecting backwards from the lower border of this cartilage is a free, peg-like process, which however is unconnected with any rib. The fourth rib appears to have no free sternal end, but is compressed between and fused with the third and fifth ribs.

The distal end of the fifth rib is free, and is connected by a narrow fibrous band with the lower border of the third rib. The sternal ends of the sixth,

seventh, and eighth ribs are separated from one another by two well-defined clefts, and are associated with the sternum by means of a broad strip of cartilage which helps to complete the costal arch on the right side. It is fused with the right side of the lower end of the sternum, and extends obliquely downwards and outwards, partly concealed by the third costal cartilage, to divide externally into two stout bars, the upper of which receives the ends of the sixth and seventh ribs, the lower bar the extremity of the eighth rib. This band of cartilage is further provided with three subordinate clefts, two above and one below, which appear to indicate the partial separation or partial fusion of three separate costal cartilages. The sternal end of the ninth rib is free, and broad, and possesses a costal cartilage which is attached by fibrous union to the above-named cartilaginous band, and helps to complete the right half of the costal arch. The distal ends of the tenth and eleventh ribs are readily distinguishable as free processes capped with cartilage which project into the abdominal wall. A deep groove separates the shaft of the tenth from that of the eleventh rib.

The sternum (fig. 9) is incomplete, and only measures three-quarters of an inch in length. It consists of an undifferentiated bar of cartilage grooved in its lower part on its anterior surface. There is no separation between pre-sternum and meso-sternum, and the meta-sternum is absent. The upper end has a shape resembling the pre-sternum. There is a shallow, suprasternal notch, on either side of which is a well-marked clavicular facet. The lateral borders receive the costal cartilages of the first three pairs of ribs. The first costal cartilages are fused with it: those of the second and third ribs are united by fibrous laminæ. The lower end of the sternum ends in a wide notch, continuous with the costal arch formed by the cartilaginous bars already described, and attaching the fourth to seventh ribs on the left side and the sixth to eighth ribs on the right side. The arch is completed by the eighth and ninth costal cartilages on the left side, and by the ninth cartilage on the right side. It is filled up by a tough fibrous membrane, which is attached to the arch, and stretches over the subjacent pericardium for a considerable distance.

The lower ribs on each side give attachment to the abdominal muscles, and from the under surface of the ninth left costal cartilage a band of muscular fibres arises—the rudiment of the left half of the diaphragm.

The conditions affecting the skeleton of the thorax are associated with the three causes already mentioned. The deficiency of the sternum is due to the ectopia: the left side of the thorax is flattened by the projection of the left lung into the ectopic sac and the consequent collapse of the ribs on that side. The rounded condition of the right half of the thorax is connected with the presence of a complete right pleural sac and lung, while the

defective formation of the ribs on the right side and their fusion together are the result of their compression by the curvature of the vertebral column.

The cavity of the thorax is much diminished in area. Its chief contents are the right lung and pleura, part of the heart and pericardium, the aorta and other large vessels, the trachea, œsophagus, and thymus gland. Under the ribs on the left side is a cleft-like space extending from the inlet of the thorax to the pleuro-peritoneum below, which is filled by a dense mass of areolar tissue naturally divisible into two layers by a fissure; one layer bounding the mediastinum and the other clothing the inner surface of the left wall of the thorax.

The right pleura is of considerable extent. Occupying chiefly the right side of the chest, it projects in the posterior mediastinum behind the heart across the middle line to the left, so as to reach the costal arch on the left side; and it also projects below the costal arch on both sides for about half an inch. It is entirely cut off from the cavity of the peritoneum by the rudimentary right half of the diaphragm, the pericardium, and peritoneum.

The right lung is ovoid in form, with the narrow end downwards. It is connected to the pleural sac by the root, and by a well-marked ligamentum latum pulmonis. It is imperfectly divided by an oblique fissure into two main lobes; and the upper lobe is partially subdivided by two slight fissures.

The left lung (fig. 2) is abdominal in position and projects downwards to the left side of the heart and above the stomach in the general peritoneal cavity. There is no left pleural sac, on account of the deficiency of the left half of the diaphragm. The lung is divided into upper and lower lobes by an oblique fissure. The root of the lung is connected with the pleuro-peritoneum behind and on the left of the pericardium, and the inner surface of each lobe is connected to the pericardium by a lateral ligament. The pericardium and heart are mainly abdominal in position, and are contained in the ectopic sac. They project below the sternum in the middle line between the two halves of the costal arch. The upper third of the pericardium is covered laterally and anteriorly by the fibrous membrane which extends from the costal margin to the skin-amnion junction. Its lower two-thirds, projecting into the ectopic sac, is covered by the pleuro-peritoneum. The pericardium is related posteriorly and on either side to the right pleural sac, which extends across the middle line behind it. The fibrous layer is prolonged upwards along the large vessels. The serous pericardium is normal, and a well-marked vestigial fold of Marshall is present. The heart, aorta, and pulmonary vessels are

also normal. The large vessels arising from the aorta (three in number) are more elongated than usual, and the only abnormality affecting the vessels in the thorax is in the termination of the left innominate vein. It joins the right innominate vein below the entrance of the vena azygos major. The ductus arteriosus is very long and arched.

The trachea is greatly elongated, measuring one and a half inches in length. It possesses twenty-five cartilaginous rings. The right bronchus is short (quarter inch). The left bronchus, elongated to the extent of one and a quarter inches, descends behind the aortic arch and pulmonary vessels in an almost vertical direction to reach the left lung.

The œsophagus passes through the thorax behind the trachea and pericardium, and between the right pleural sac and the general peritoneum. Before reaching the stomach it passes between the two parts of the diaphragm, right and left.

The thymus gland is large. It is normal in position and form.

The nerves of the thorax, phrenic, and vagi are normal in their course through the cavity. The phrenic nerves are both small, and are traceable to the right and left halves of the diaphragm respectively.

Of the *cervical region* of the specimen little need be said. It is normal in all respects. The infra-hyoid muscles are present, and the thyroid body, of which the left lobe was partially separate, possesses a well-marked pyramid extending up to the hyoid bone.

There can be no doubt that these conditions of the vertebral column and thorax are the direct consequence of the ectopia and the spina bifida. The conditions of the ribs and sternum, moreover, have a particular interest from the light which they throw on the question of the development and morphology of the sternum.

The ectopia has admittedly caused arrest in the development of the sternum ; but the arrested condition gives absolutely no support to the view of the formation of the sternum by the fusion of costal cartilages. On the other hand, while no evidence from such a condition as this can be regarded as altogether conclusive, the condition of the sternum in this case lends material support to the view which ascribes to the sternum an independent origin. There is a median cartilaginous plate arrested in its downward growth by the ectopia, directly associated with only three pairs of costal cartilages, and joined at its lower end on each side by the fused and elongated costal cartilages of certain succeeding ribs. There is no differentiation of pre-sternum and meso-sternum, there are no centres of ossification, there is a failure of certain ribs (fourth and fifth on the right side) to reach the sternum at all, and the meta-sternum is absent altogether.

General Conclusions

Conditions more or less similar to those described above have been recorded and discussed by other observers (1–10, 14–18), and notably by Dakin (4) and Bryce (3).

The essential features in these cases appear to be ectopia, retroflexion of the spinal column, and defective formation of the hind-gut, with the presence of a cloaca. Commonly associated conditions, not however always present, are spina bifida and hydrocephalus internus, persistent vestiges of a neurenteric canal, defective formation of the thorax and diaphragm, and separation of the pubic bones with dorsiflexion of the lower limbs.

Some of these associated conditions may of course be only accidental and coincident. For example, the spina bifida and hydrocephalus, while stated by Duncan and Hurry (5) to be usually present, are shown by Dakin to be sometimes absent. Again, it is possible that the spina bifida and hydrocephalus may not be causally connected. While hydrocephalus internus appears as a common occurrence in cases of spina bifida, it is not essential. Indeed in the present case, while it is evident that the spina bifida was formed at a comparatively early stage in embryonic development, the cerebral affection appears to have arisen at a much later period, and possibly as a consequence of meningitis. The cerebral convolutions are well marked, and the conditions of cerebral development are generally advanced.

On the other hand, it is possible that the conditions present in such a case may all be more or less correlated, and associated by some common cause.

There is no doubt that we must go back to a very early embryonic stage to find a condition which may be regarded as the starting-point of these malformations. Professor A. R. Simpson (16) suggests a time between the fourth and seventh week of fœtal life. Bryce (3) has drawn attention in this connection to the conditions of the vertebral column, which several embryologists (notably His) have described as strongly retroflexed in the mid-thoracic region at the end of the first month. It is not known if this is a normal, or only an occasional, condition. It is sufficiently common, however, to be recognised under otherwise normal conditions as a transitory condition which disappears as the abdominal walls close in.

The period at which arrest of development has occurred appears to be after the formation of the cloaca, but before the separation of rectal and genito-urinary passages; there is no phallic papilla; the proctodœal invagination has occurred, but failing to unite with the rectum, projects into the cavity of the cloaca as a cloacal papilla. The kidneys and ureters are well

formed, and the latter end in the lateral recesses of the cloaca. At least one genital duct is present. The union between neural and alimentary canals presists as a fibrous cord (neurenteric canal), and the condition of spina bifida has arisen after the development of the nerve roots from the medullary tube.

Under normal conditions the body walls close in, *pari passu*, with the formation of the umbilical cord and umbilicus; and simultaneously the cloaca and genital papilla proceed to form anus, genito-urinary sinus, and external genital organs.

Most if not the whole series of malformations appear to have been primarily caused by the failure in development of the hinder portion of the alimentary canal.

The whole of the large intestine appears to be represented by the pseudo-cæcal pouch with its two appendages: it retains its primitive connections with the spinal cord, and terminates in a cloacal chamber. The proctodœal invagination, failing to meet the terminal portion of the rectum, produces a cloacal papilla.

One of the most striking results of the defective formation of the alimentary canal is the absence of the allantois. The ventral wall of the cloacal cavity is deficient, forming the internal cloacal aperture; and there is no vestige of allantoic diverticulum or allantoic stalk, so accounting for the absence of a true bladder and the presence of the ectopic sac.

The wall of the ectopic cavity is formed by the amnion; and the cavity itself represents the persistence of the embryonic and extra-embryonic parts of the cœlom. In normal circumstances the growth of the allantois from the hinder end of the alimentary canal along the amnion to the chorion, besides assisting in forming the placenta, moors the embryo to the uterine wall, and is of obvious assistance in the subsequent process of closure of the abdominal wall and formation of the umbilicus. The absence of the allantois has, *inter alia*, permitted the projection of the viscera into the extra-embryonic cœlom, and the persistence and enlargement of that space into an ectopic sac.

That the bladder is absent in the case described there is no doubt. Instead, the ureters terminate in the upper ends of bilateral, thick-walled sacs, which communicate with the cloacal cavity by slit-like openings. These are to be regarded as dilatations of the lateral walls of the cloaca. The true urinary bladder, it is true, arises from the cloaca, but the most reliable accounts of its formation (Fleischmann (6)) lead us to the conclusion that it is essentially (1) median and ventral, and (2) formed from the allantoic diverticulum, absent in this case. The share taken by the cloacal cavity is confined to the formation of the trigone of the bladder and

the genito-urinary passages. In the instance under discussion the ureters retain their primitive relation to the side walls of the cloaca, communicating through these bladder-like sacs with the cloacal cavity below the termination of the gut.

The retroflexion of the spinal column has been much discussed. It appears to be a usual occurrence in these cases; and its causation is obscure. It may be the persistent embryonic flexure; it may be due to the collapse of the vertebral column into the ectopic sac, owing to the defective formation of the abdominal wall; it may be associated with the spina bifida, and be occasioned in part by the weakness in the column due to the deficiencies in the formation of the spinal laminæ; it may, again, be caused by the want of union of the pubic bones, and the dorsiflexion of the lower limbs on the trunk: or all these causes may be at work together.

There is no doubt that the retroflexion of the column has occurred at an early period; at a time when the vertebral laminæ are incompletely formed, when the cartilaginous column has been only incompletely segmented to form the vertebral centra; after the development of the spinal nerve roots, but prior to the time when the cord of connection (neurenteric canal) between the neural and alimentary canals has been separated.

It does not seem that the spina bifida can be traced into direct causal connection with either the ectopia or the retroflexion of the spinal column, though, as stated already, both spina bifida and hydrocephalus are very usually found as concomitants of the condition of ectopia. The causes of both spina bifida and hydrocephalus are so obscure that it seems useless to enter on a discussion of that aspect of the subject here. It has been already stated that, in our opinion, the internal hydrocephalus appears to have a later date of onset than the spina bifida, which for several reasons may possibly be associated with the ectopic condition. It is possible that the two conditions have arisen from distinct and separate causes.

The dorsiflexion of the lower limbs and the collapse of the left side of the chest are commonly associated conditions in ectopia. Both are related to the retroflexion of the spinal column, and the collapse of the ribs on the left side is further associated with the deficiency of the diaphragm. It is possible also, as Dakin suggests (4), that pressure effects are exercised on the growing fœtus by the uterine wall, which, without necessarily irritating, may have the effect of maintaining and exaggerating the conditions found.

The remarkable family likenesses which the recorded examples of these conditions present leads one to the conclusion that in all there is some essentially similar exciting cause. An arrest of development of the hindgut is the result, leading to secondary results which indicate that the whole

process of development of the associated parts pursues a wrong course, but in all cases on more or less similar lines. This exciting cause is quite obscure, and must begin its operations at a very early period in development.

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ON THE ANATOMY OF THE CALAMUS REGION IN THE HUMAN BULB; WITH AN ACCOUNT OF A HITHERTO UNDESCRIBED "NUCLEUS POSTREMUS."

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Part II.[1]

§ VII. Description of Type represented by Specimen 6, characterised by the Presence of an "Intercinereal Commissure."

It has previously been stated that the condition exemplified by the section-series just examined is not by any means an invariable one.

The specimen whose anatomy is illustrated by the stereophotographs in figs. 12–14 offers an example of a structural arrangement differing, at first sight, somewhat markedly from that just described. It has been pointed out that in this specimen the obex overhangs two openings, one ventral to the other, into both of which the ventricular cavity appears to be prolonged.

The more ventral of the two canals forms a very evident tunnel into which is continued, in a caudal direction, the median furrow of the floor of the ventricle (*cf.* figs. 13 and 14). The dorsal boundary of the ventricular aperture of this tunnel consists of a very definite solid bridge of nerve-tissue formed by a fusion, across the median plane, of the caudal prolongations of the alæ cinereæ. This arrangement will be still better realised with the aid of the stereograph shown in fig. 22, A and B, which was taken from the same specimen prior to removal of the false or membranous obex. From this figure it is also apparent that the ventricular aperture of this ventral moiety of the central canal lies in a transverse plane which is some distance in advance of (*i.e.* cephalad) of the apex of the calamus. Now, it is probably a ventral tunnel of this nature which Ziehen has taken as the proper "central canal" in his fig. 176, whilst the roof of it, which in the accompanying text he quite erroneously names the obex, is doubtless of a character more or less similar to the bridge of tissue now described and figured. It has already been pointed out that a similar condition was recognised by Henle, and was interpreted by him as a second mode of termination of the central canal. But his illustrative fig. 145 may best be explained, in the light of the facts

[1] Part I. of this paper appeared in the preceding (*i.e.* April) number of this Journal. Figs. 1–21 will be found in connection with Part I.

now presented, as representing a condition due to median coalescence of a portion of the walls of the deep vertical median furrow of the neural canal, extending for a short distance in front of the calamus. It is true that in Henle's figure the coalescence does not affect precisely the same morphological region of the parietes of the neural canal as that involved in the case now described and figured. But it will appear in the sequel that fusion of opposing portions of the wall of the neural canal of the bulb may occur at various levels, producing varying conditions. In a transverse section of another specimen I have found an arrangement identical with that figured by Henle, in which the process of median fusion has affected, not the region corresponding to the accessorio-vagal nucleus, but rather the region intermediate between the latter and the hypoglossal nucleus.

It is further clear from fig. 14, A and B, that the cavity of the fourth ventricle extends caudally, not only into the ventral tunnel above described, but also dorsally to the fusion or commissure bridging over the latter, into a space immediately under cover of the false obex. The lateral walls of this space are formed almost entirely by very marked, prominent, cushion-like masses. These are the caudal continuations of the areæ postremæ of Retzius, which are seen rapidly diverging as they are traced frontally into the hinder portion of the floor of the fourth ventricle. A moderately deep sulcus separates each area postrema dorsally from the ragged remains of the membranous obex and ligula; and a deep furrow also limits each ventrally from those caudal prolongations of the alæ cinereæ which unite to form the commissure constituting the floor of the space under consideration. When this commissure is absent, we then find under the obex a simple, cleft-like central canal of considerable dorso-ventral extent, into which the cavity of the fourth ventricle narrows, as we trace it backwards. This is the condition which is illustrated in the stereograph in fig. 7, A and B, as well as in the sectional figures 9, 10, etc.

The specimen whose gross anatomy is illustrated by the stereographs in figs. 12–14 and fig. 22, was embedded and cut into serial transverse sections. Owing to the preliminary dissection, whose results are visible in fig. 14, the dorsal- or roof-region of the neural canal in the vicinity of the calamus is necessarily highly imperfect and mutilated. Fig. 23 represents part of a transverse section across the bulb immediately anterior to (cephalad of) the commissural connection between the caudal prolongations of the alæ cinereæ. The steeply sloping floor of the caudal part of the fourth ventricle is seen ascending on each side from the median sulcus of the ventricular floor. Three prominences are seen on each side. The most ventral is the funicular continuation backwards of the trigonum hypoglossi. These two opposing hypoglossal funiculi are, ventrally, partly in

contact with one another. Dorsal to this is the still more prominent caudal prolongation of the ala cinerea, which is, in this plane, of considerable superficial extent. Dorsal to this again is the sharply marked prominence of the somewhat peculiar loose tissue, forming, on the surface, the area postrema of Retzius. The dorso-lateral limit of the latter on the left side shows a vestige of the attachment of the tænia ventriculi or ligula. The ependymal epithelium of the ventricular floor may be traced as far as this latter limit. In spite of the numerous accidental specks upon the section, it is not difficult to recognise the neuronic groups composing the nuclei of the hypoglossus and vago-accessorius.

Part of a transverse section at a slightly more caudal (0·55 mm.) plane is represented in fig. 24. Here the section passes through the region of fusion or commissural connection above referred to. It is plain that this commissure, whatever its physiological significance, structurally connects, and may be looked upon as a median fusion of, the vago-accessorial columns or funiculi of opposite sides, and may therefore appropriately enough be named the "intercinereal commissure."

The ventricular ependymal epithelium may be well seen clothing the dorsal aspect of the commissure. Here, on each side, it dips into the well-marked "dorso-lateral" sulci between it and the areæ postremæ (where it is specially thickened), and extends in a dorsal direction over the surface of the area postrema as far as the region where it becomes defective owing to the mutilation due to previous dissection. It is obvious that the space here seen, between the prominences of the areæ postremæ of opposite sides, is the space immediately overhung by the membranous obex, and well seen, after removal of the latter, in fig. 14.

The narrow, ventral, cleft-like moiety of the lumen of the neural canal, visible in fig. 24, is slightly widened immediately beneath the intercinereal commissure; and this widened part of it is definitely marked off on each side from the remainder of the cleft by the continuation of the ventro-lateral furrow which was visible in the preceding fig. 16. At the present level the median coalescence of the cinereal funiculi has therefore not extended right down to the ventral limit of these columns. On the other hand, their coalescence has extended, dorsally, quite up to the deeply inflexed dorso-lateral sulci. Ventrally to the ventro-lateral sulcus the vertical walls of the cleft-like lumen are slightly indented by other, asymmetrical, furrows. These are similar in character to that visible in a corresponding position on the right side in fig. 23. They represent sections through some of those more or less oblique furrows whose existence on the surface of the funiculus teres (hypoglossi) in the floor of the ventricle, a little higher up, determines the appearance of the "area plumiformis" of Retzius.

The photomicrograph reproduced in fig. 25 represents the corresponding region in a section cut 0·6 mm. further on in a caudal direction. Here the intercinereal commissure is met with in even fuller development, owing to the further extension, in a ventral direction, of the area of median coalescence. One result of this ventral extension is that the ventro-lateral sulcus has been encroached upon and obliterated by the commissural connection. The dorsal supracommissural portion of the neural canal, though still wide proportionately to the ventral infracommissural portion, is considerably narrower than in the previous figure. This is owing to the closer approximation of the two opposing "areæ postremæ." Continuous with the dorso-lateral limits of the latter are to be seen vestiges of the lateral parts of the roof, in the shape of the "tæniæ" or "ligulæ." Laterally to these again may now be seen small portions of the clavate enlargements of the funiculi graciles, which are also becoming more approximated to one another as they are traced in a caudal direction. Fig. 26 illustrates a section 1·1 mm. lower down in the same bulb. Here there seems to be a marked change in the structural condition, but it is more apparent than real. Dorsally the funiculi graciles have undergone still further convergence, so that the roof-area of the neural canal is greatly narrowed. A remnant of the roof-plate is visible on the left side, its inflexion marking the angle between the roof and the lateral wall of the now cleft-like supracommissural portion of the neural canal. The lateral walls of this supracommissural space no longer exhibit prominent areæ postremæ, but they are nevertheless still occupied by the caudal continuations of the loose tissue peculiar to the latter. The dorso-lateral sulcus is still tolerably evident on the left, but less so on the right, where it appears to lie, not opposite the left, but on a more dorsal plane. This is doubtless referable to some obliquity in the plane of section. Remains of the intercinereal commissural are still present, but its continuity is becoming interrupted by median defect in its dorsal portion. The section in fact just grazes the posterior or caudal end of the commissure proper.

The next section, illustrated in fig. 27, was only 0·15 mm. caudal to the last. At a first glance it might appear that the intercinereal commissure still persisted, but this is not the case. Comparison of figs. 26 and 27 will show that the tissue-bridge in the former (which lies in an oblique line drawn between the large oval blood-vessels on either side of the median plane), has, in fig. 27, entirely disappeared. The caudal limit of the intercinereal commissure proper has now been reached. The new median tissue-bridge, uniting the lateral walls of the cleft-like cavity in fig. 27, is a new formation and lies in a more dorsal plane than that occupied by the intercinereal commissure. Comparative measurements

indicate that it has been formed, at least in part, at the expense of the deepest portion of what has here been called the "supracommissural" portion of the neural canal. Had the entire intercinereal commissural connection abruptly and completely terminated, then of course the continuity of the supra- and infra-commissural parts of the cleft-like neural canal would necessarily have been restored. And this may, in fact, occasionally happen. Indeed, such a condition is here very nearly attained. But, actually, just as the hinder end of the intercinereal commissure is reached, a new median fusion commences, which is more or less continuous with the dorsal caudal portion of the disappearing commissure. As we pass backwards this new area of median fusion rapidly —almost abruptly—extends in a dorsal direction, totally obliterating the entire dorsal moiety of the lumen of the neural canal. In the section at present under consideration, however, the latter is still preserved, walled in laterally by the caudal prolongations of the areæ postremæ, and roofed over by a somewhat thickened roof-plate which will be recognised as morphologically a genuine obex, albeit of such diminutive cranio-caudal proportions as to be quite unrecognisable during the preliminary surface-dissection. It must be regarded as having formed the medullary substratum of the caudally placed apex of the triangular membranous or false obex shown in the stereograms in figs. 13 and 22 (*cf.* figs. 8–10 from the previously described specimen).

The last section illustrated from this series is shown in fig. 28. Here the median fusion, begun in the previous section, has quite obliterated the dorsal half of the neural canal. Still, the roof-mass corresponding to the obex is clearly distinguishable. It arches over a small light area of loose tissue representing the most dorsal part of the lumen of the canal, and in which, under higher magnification, are to be discovered distorted remains of the ependymal lining.

Fig. 29 is a schematic plane-reconstruction from the section-series, representing a vertical projection or side elevation of the lateral wall of the cleft-like neural canal from a short distance in front of the cranial extremity of the intercinereal commissure to a short distance caudal of the plane illustrated by fig. 28. It is plotted out to the same scale of magnification as that of the photomicrographs of the sections, *i.e.* 24 diameters. The base-line represents the horizontal plane of the floor of the ventral median furrow of the neural canal. The dotted line above represents the plane of the attached margin of the roof. It will be observed that the distance from floor to roof is approximately constant. The left end of the diagram is cranially directed. There the two sulci of the lateral wall ("floor") of the ventricle—dorso- and ventro-lateral—

are seen limiting between them the caudal prolongation of the ala cinereal funiculus. This is seen to merge in the shaded area representing the intercinereal commissure. Caudally this is seen to end abruptly, except for its partial continuity with that more extensive, and more dorsal, median fusion, in which the caudal prolongations of the area postrema (or dorsal longitudinal zone of the medullary wall) becomes merged. But the caudal end of the diagram would also tend to suggest that, with the genuine dorsal zone, behind the intercinereal commissure, there is also merged part, at least, of the intermediate zone of the medullary parietes,

FIG. 29.—Scheme of plane reconstruction from the serial sections of specimen VI., showing lateral projection, or side elevation, of "intercinereal commissure" and the most anterior (frontal) portion of interpostremal fusion. *d.l.s.*, dorso-lateral sulcus; *v.l.s.*, ventro-lateral sulcus; *i.c.com.*, intercinereal commissure; *s.c.r.*, supracommissural recess; *i.p.*, interpostremal median fusion.

so that the patent part of the lumen would correspond only with the ventral longitudinal zone, or to that with a part of the intermediate zone.

With figs. 24 and 25 it is instructive to compare fig. 21, which represents the same region in a section of a human fœtal medulla oblongata of the sixth month.

Here the area, or rather the *eminentia*, postrema stands out very prominently on each side, at the bottom of the wide depression between the funiculi graciles.

Unfortunately, as the section was not prepared for the purposes of this paper, but a number of years ago, the membranes have not been preserved, and it is impossible in the section itself to demonstrate the precise dorsal limit of the ependymal epithelium. Still there is not the slightest doubt that it terminated dorsally by reflection into a pia-

ependymal roof at the slightly ragged dorso-lateral limit of the eminentia postrema, and that the latter was wholly intraventricular. In this respect the parallel with fig. 25 is perfect. Also the "dorso-lateral sulcus," of the ventricle, bounding the eminentia postrema ventrally, is exactly comparable with that in the figure cited. Here it is seen to be markedly inflected, and the bottom of the sulcus is lined with specially elongated ependymal epithelial cells, whose basal processes are prolonged into a leash of ependymal fibrils forming a definitely specialised neuroglia septum.

A photomicrograph illustrating the details of this arrangement on a higher scale of magnification is reproduced in fig. 21A. This neuroglia septum is seen to form a very distinct ventral limit for the peculiarly specialised tissue of the eminentia postrema. (Fig. 30, from an adult specimen, to be later on referred to, illustrates the same neuroglia septum.)

Ventrally to the dorso-lateral sulcus of the neural canal the cleft-like lumen is bounded by the vertically extensive "funiculi cinereæ" (fig. 21.) Between these there is no median coalescence or intercinereal commissure. They are limited ventrally by the shallow but well-marked "ventro-lateral sulcus" of the neural canal, ventral to which is the caudal continuation of the funiculus teres hypoglossi.

§ VIII. Discussion of Figures from Retzius's Work which indicate the Existence of a Similar Commissural Structure. Significance of the "Funiculus separans" of Retzius.

The occasional presence of such a commissural connection as has just been described and illustrated has not entirely escaped recognition. Variations due to its presence, in different grades of perfection, are to some extent responsible for the discrepancies in the different accounts of the central canal at its confluence with the fourth ventricle. The small tissue-bridge which, as already noted, Ziehen has erroneously taken for an obex, was probably of somewhat similar commissural character. We have also seen that in one of Henle's descriptions the existence of a similar condition is implied.

Retzius (1896) has clearly recognised and figured the occurrence of a commissural connection which is evidently identical with that above described. His fig. 4A, Taf. xxxviii., represents a sagittal section through a specimen of this character; and his fig. 14, Taf. xxxv., is also in tolerably close correspondence with it.

Unfortunately, the plan of Retzius's work did not extend to the sectional anatomy of his specimens, or only in a very minor degree, and hence

the morphological value of various features recognised was sometimes unperceived.

More lately Streeter (1903) has endeavoured to supplement Retzius's description by an investigation of the sectional anatomy of the bulb, in order to ascertain precisely the correspondences between the surface-features, as recorded by Retzius, and the sectional structure. He has found, *inter alia*, that the "glistening, light-coloured ridge," to which Retzius gave the name of "funiculus separans," is due to "a thickened ependymal overlying the vagus nucleus." This is undoubtedly correct, but Streeter does not make it clear that the funiculus separans by no means covers the whole of the prominence corresponding to the vagus nucleus. This, however, is obvious even from Retzius's own figures already referred to (figs. 4A and 4B, Taf. xxxviii.). In the opinion of the writer, the funiculus separans has, in Retzius's descriptions, attained to a distinction out of proportion to its structural importance. It is, as Streeter has shown, merely a thickened ependyma ridge. The unnecessary exaltation of this mere surface-thickening has led to the obscuring of the really important fact that the ala cinerea is, in ordinary cases, as definitely prolonged caudally into the lateral wall of the central canal as is the funiculus teres hypoglossi. It may be suggested that this fact deserves recognition by the use of such a term as "funiculus cinereus." The condition indicated is very apparent in the stereograph (fig. 7, A and B), from a case uncomplicated by the occurrence of any commissural connection between the opposing funiculi.

The "funiculus separans" is very variable in its degree of prominence. It usually skirts the dorsal margin of the cinereal funiculus, overlapping and encroaching upon the surface of the latter, and in some cases appearing as if it formed a definite caudal boundary for the "trigonum vagi." It is important to recognise that, where Retzius describes and figures the funiculi separantes of opposite sides as fusing across the median plane (as in his fig. 4A, Taf. xxxviii.), it is really the cinereal funiculi which undergo fusion in the "intercinereal commissure" above described; although, of course, the funiculi separantes may also be involved in the fusion.

Fig. 31, A and B, represents a stereograph of the caudal extremity of the fourth ventricle in another case, uncomplicated by median fusion, near the calamus, in which the genuine prolongation downwards, into the aperture of the central canal, of a funiculus cinereus, may be readily verified. The funiculus separans is here distinctly visible, especially on one side, as a slender and inconspicuous ridge, skirting and overlapping the dorsal part of the surface of the cinereal funiculus, and continued forwards to gain the surface of the trigonum acustici, in consonance with Retzius's account of it.

Fig. 32, A and B, illustrates the same points in the case of the bulb of a human fœtus in which the funiculus separans stands out sharply as an insignificant white stria parallel to and close to the dorsal border of the funiculus cinereus. It lies just ventral to the dorso-lateral sulcus, between the latter and the elongated, cushion-like prominence of the area postrema. Again, in the stereograph reproduced in fig. 14, A and B, the funiculus separans is visible, and here it is perfectly evident that the massive intercinereal commissure is formed, not of mere funiculi separantes, but of the connected vago-accessorial columns or cinereal funiculi. It is in the light of this figure that Retzius's fig. 4A, Taf. xxxviii., and fig. 14, Taf. xxxv., are to be interpreted.

The stereographs referred to in illustration of the foregoing statements also show that, at the caudal extremity of the fossa rhomboidalis, in cases uncomplicated by median fusion, we find three columnar elevations disappearing under cover of the obex into the rapidly narrowing but dorso-ventrally elongated central canal of the bulb. These are the funiculus hypoglossi, the funiculus cinereus (mihi), and the area or rather eminentia postrema. And these three longitudinal (or oblique) elevations are separated from one another by more or less well-marked sulci. The funiculus separans may be ignored as a mere superficial ependymal stria. It is true that these three columns can only be traced a short distance, as separate elevations, along the lateral wall of the central canal, which rapidly, and often abruptly, decreases in its dorso-ventral extent. It is well known, however, that the central canal, in spinal cord and bulb, undergoes during development a marked reduction dorso-ventrally; and it is, *a priori*, reasonable to believe that in this reduction the morphological constitution of its parietes may become undecipherable.

§ IX. The Occurrence of "Interpostremal Coalescence" and the Relation of the Obex to such Fusion.

This abrupt dorso-ventral reduction, which the lumen of the cleft-like central canal ordinarily undergoes as it is traced caudally, has already formed the subject of remark in connection with the consideration of figs. 26–28, together with fig. 29. There it was seen to be effected through obliteration of the dorsal moiety of the canal, from adhesion of those parts of the lateral walls which were formed by the caudal prolongations of the areæ postremæ. In this connection it is necessary to examine a statement of Retzius in his account of the area postrema in the fœtal brain (1896, p. 42). Retzius remarks that the obex, when present, "liegt an dem hinteren Umfang dieser beiden paarigen Parteien (areæ postremæ) und bildet

gewissermassen eine Brücke zwischen ihnen. Die beiden Parteien scheinen aber sonst nicht dem eigentlichen Randsaum der Rautengrube anzugehören —denn dieser liegt hinter ihnen—sondern sie tauchen vielmehr aus der Ausgebung des Centralkanals empor. An ihrem hinteren Rande setzt sich die Pia mater, in der Regel mit scharfer Kante, an; hier ist auch der Rand des Foramen Magendii zu suchen." Now there can be no doubt that, as has already been shown, the areæ postremæ, when traced caudally into the vestibule of the central canal, do sooner or later unite in a median fusion. But it is not the median fusion of these which constitutes the obex; nor is it correct to say that the obex forms a bridge *between* the caudally converging areæ postremæ, as suggested in the first portion of the passage quoted. The second sentence in the quotation, however, indicates and implies the genuine relationship of the obex, for the latter *does* belong to the proper "Randsaum" of the roof of the ventricle; and, when fusion of the opposing areæ postremæ begins relatively high up (frontally) in the region of the calamus, their coalesced mass is bridged *over* by the obex. Nevertheless, fused or unfused, they themselves belong, not to the roof or the "Randsaum," but to the dorsal portion of the lateral wall of the neural canal in this region. Since, however, the obex, representing the roof-plate, immediately adjoins the dorsal edges of the areæ postremæ, it follows that complete coalescence of the latter across the median plane necessarily destroys the individuality of the obex, so that it comes to appear simply as the most dorsal part of a mass of tissue, the main bulk of which is composed of the fused areæ postremæ (*cf.* esp. figs. 27 and 28).

It is a condition such as this which is represented in Retzius's illustrative fig. 4 on his Taf. xxxv. In figs. 1, 2, and 5 on the same plate, the condition appears doubtful, though in fig. 5 I suspect that the median fusion of the areæ postremæ did not involve their entire extent, and that the obex had therefore in some degree retained its individuality.

The stereograph herewith reproduced in fig. 33, A and B, illustrates a human fœtal bulb, etc., in which dorsal median fusion of the areæ postremæ has largely masked the individuality of the obex, which therefore appears as incorporated with the commissure between the former. Here the delicate membranes, including the tela choroidea, have, of course, been completely stripped away in the specimen, but the line of attachment of the tænia is still faintly visible under stereoscopic inspection, skirting the dorsal margin of the prominence of the area postrema, and is traceable caudally into the deep depression between the very prominent clavæ.

That a more partial median fusion of the areæ postremæ may occur ventrally to, and structurally independent of, the obex, is proved by such figs. as Retzius's fig. 7, Taf. xxxv., from an adult medulla oblongata. The

fœtal condition exemplified in fig. 33 is further illustrated by the sectional figs. 34–37, which are photomicrographs of portions of four of the serial transverse sections obtained after paraffin embedding.

Fig. 34 illustrates the most frontal of the planes represented. It passes through the bulb just where the areæ postremæ are coming into tolerably close proximity with one another during their rapid caudal convergence (*vide* stereographic fig. 33). In the lateral ventricular walls are seen the three columnar elevations to which reference has frequently been made in the preceding pages. The ventral of these (hypoglossal column) is limited in extent.

The pia-ependymal roof is necessarily lacking, since it was removed before the stereograph in fig. 33 was taken. But one may still discern the site of its bilateral attachment, at the dorso-lateral angles of the areæ postremæ. As far as these points on each side, the entire ventricular walls are lined by ependymal epithelium. This is different in character in the ventral and dorsal portions of the canal. Dorsally from the well-marked "dorso-lateral sulcus" the ependymal epithelium is flattened and inconspicuous. It is, nevertheless, quite easily discernible, covering the prominence of the area postrema as far as the site of attachment of the membranous roof-plate. Ventrally from the dorso-lateral sulcus, the ependymal epithelium is markedly columnar, where it covers the elevations corresponding to the vago-accessorial and hypoglossal nuclei. These two elevations are separated by the slight but distinct representative of the "ventro-lateral sulcus."

Fig. 35 shows the gradual narrowing of the ventricular cleft. In its most dorsal region, however, the cavity still widens out horizontally under the thin and widely extended roof-plate (absent in the section).

Fig. 36 represents a section which just grazes the anterior or frontal border of the interpostremal commissure which is visible in fig. 33. Note, however, the continued presence, dorsally to this median coalescence, of the thin ependymal lining of a suprapostremal recess of the ventricular cavity. The interpostremal coalescence is rapidly producing obliteration of the original dorsal moiety of the cleft-like ventricular cavity, whose uncomplicated form is so well illustrated in figs. 9, 10, etc. At the same time, the original configuration of the lateral walls of the cavity has now become unrecognisable.

In the next figure (fig. 37) the interpostremal coalescence is practically complete: but dorsally to it there is still to be seen the remnant of the suprapostremal ventricular recess, represented by part of its flattened epithelial ependymal lining. Immediately caudal to the plane of this section, the thin pia-ependymal roof-plate in the angle of the calamus—

which alone represented the obex in this case—became adherent to the dorsal aspect of the interpostremal commissural mass. This incorporation of the membranous representative of the obex with the latter occasioned final obliteration of the suprapostremal ventricular cavity. But it is obvious that the total removal of the membranous roof-plate, during the preliminary dissection, involved the complete destruction of the obex-representative.

§ X. Summary of Staderini's Observations on the Mode of Transition from Central Canal to Fourth Ventricle. Criticism of his Views.

Staderini is the only writer known to me who has attempted to deal at length with the details of the transition from central canal to fourth ventricle.

The following summary of Staderini's views and observations has been compiled with the aid of abstracts in Merkel and Bonnet's *Ergebnisse* for 1894 (Bd. iv. p. 235), and in the *Ital. Arch. de Biol.* (xxiii. p. 456, 1895), together with the text of the original paper itself (1894):—

In the bulb there exists for a certain distance, besides the central canal, another dorsally placed space. The two canals gradually widen out towards the brain, finally become confluent, and open in common into the ventricle after they have passed the plane of the calamus scriptorius. The presence of this double canal is to be explained by the fact that, dorsal to the central canal, in the place where the dorsal columns separate from one another, the substantia gelatinosa individualises itself and appears as a wedge dividing the posterior commissure in its entire height into two similar halves: the point of the wedge forms the roof of the central canal: the base is at first covered by pia but further cephalad; this is raised up, and there appears immediately under it a thin membranous continuation of the tela of the fourth ventricle. This is separated by a small space from the surface of the wedge, and is united to it at the sides, thus walling in the space. When one proceeds upwards, this cavity dilates further, and then on the surface of the wedge of substantia gelatinosa a furrow appears, finally splitting it up so that the central canal and this dorsal space come into communication. Their cavities unite, and are continued onwards into the fourth ventricle. Staderini finds the explanation of this arrangement in development. In the central canal, at a certain period, two lumina appear owing to contact of portions of the lateral walls. The dorsal of these is destined to disappear. In the bulb, obliteration of the dorsal cavity

fails to take place. The author is of opinion that from these facts one can better explain the resemblance in the arrangements of the fossa rhomboidalis.

It is obvious that the developmental explanation put forward by Staderini is in general agreement with that worked out in the earlier sections of the present paper. And it will further appear that the fully developed condition which has been described by Staderini is practically identical with one of the several varieties of the transition-region between central canal and fourth ventricle, which I have distinguished in the course of my descriptive account of the different specimens. The only case which seems to answer precisely to the type recognised by Staderini is that which is illustrated in figs. 34–37. But the mode of statement adopted by Staderini in his description of this case, though not inaccurate, seems to me to be far from happy, and tends to convey a quite inadequate conception of the real nature of the structures met with. This is no doubt attributable to Staderini's failure to recognise the existence of several varieties of conformation in this region; and, in particular, of that simple, uncomplicated type which we have traced and illustrated in figs. 9–10 and 16–19. It is the occurrence of this type which enables us most readily to connect the adult condition, in its several varieties, with that met with in the embryonic condition.

There are, however, in addition, certain criticisms in detail which must be passed upon Staderini's account of the particular variety which he regards as typical. In the first place, the "wedge of substantia gelatinosa" of which he speaks cannot be other than the product of the interpostremal coalescence to which I have called attention. The "splitting" in two of this "wedge" is simply an awkward and obscure presentation of the fact of that coalescence of which Staderini himself seems to be aware, as a developmental fact.

In the second place, Staderini has made no reference to the part which the obex plays in the process to which he has referred. It is not clear that he has wholly avoided a confusion between a suprapostremal recess, which lies *ventral* to the plane of the true obex or its representative, and an ependymal recess *dorsal* to the plane of the obex. The latter is the representative of a portion, at least, of Blake's "caudal evagination" of the membranous ventricular roof; whilst the former is the dorsal moiety of the original cleft-like central canal immediately below the point at which it opens into the fourth ventricle.

§ XI. Microscopical Anatomy of the Area Postrema. The "Nucleus Postremus."

Attention has, in a previous section of this paper, been drawn to the peculiar histological characters of the area postrema and its caudal continuation.

These characters have not escaped notice. Retzius originally described the area postrema as a peculiar, grey, spongy-looking area.

Blake (*loc. cit.*) claims to have ascertained that the "area postrema" is the ventricular aspect of the "secondary rhomboidal lip" of His, as present in the lower part of the fourth ventricle. This appears, he says, "in frontal sections advancing cephalad of the obex," "as a well-marked, rather vascular body which can be readily recognised as staining deeply, especially in advanced embryos. Figs. 28 and 31, human; fig. 33, cat. It is usually closely fused with the oblongata, but the line of division as a rule can be identified by the entrance of vessels." Blake's fig. 31, in particular (from a human foetus at full term), coincides very closely with the general appearance of the sections I have obtained from the same region in the adult. Blake, however, gives no further account of the microscopical anatomy of the "area postrema" beyond the designation of it (quoted above) as a "rather vascular body" . . . "staining deeply."

It will appear from the account I have given above of the area postrema, that I cannot accept Blake's interpretation of its morphological nature. The mere fact that one is able to follow the area postrema in a caudal direction into the lateral wall of the central canal, as in figs. 19, 9, and 10, is itself sufficient to contradict the view of its homology with the secondary rhomboidal lip. And indeed one can still trace the prolongation of the peculiar tissue of the area postrema well below the levels represented in the figures cited.

In his paper already referred to, G. L. Streeter (1903) deals more specifically and expressly with the structure of the cross-section of the medulla-oblongata in relation to the topographical features of the floor of the ventricle as described by Retzius; and, amongst other points, with the microscopical anatomy of the region corresponding to the area postrema. Though, however, the structure is correctly (but, for our present purpose, inadequately) figured in the author's Plate III. fig. 4, nothing is added to Blake's conception of its nature. The following statements embody Streeter's observations with regard to the latter question: "The space between the attachment of the tela and the median line is divided by surface-furrows into three areas. The outermost area consists superficially of a loose vascular tissue, similar in structure to the vascular area seen in

sections 1 and 2. Here it corresponds to the area postrema of Retzius." . . . . "It will be observed in section 4 (Pl. III.) that the area postrema does not represent an intraventricular part of the nuclei of the posterior columns of the cord, but is a vascular structure overlapping the vagus nucleus, and associated in structure and position with the obex, tela choroidea, and the wedge-shaped area seen in fig. 2" (p. 305).

These statements fail to throw much light on the nature of this interesting area. All accounts agree in recognising the more vascular character of the grey matter of the area postrema. The degree of its vascularity is, however, subject to some variation. As a rule it is permeated by numbers of small arteries and arterioles with relatively thick muscular walls. But in addition to this abundant vascularity, the grey matter of the area postrema is characterised by a remarkably loose and open texture of its myelospongium, in virtue of which the tissue possesses great delicacy and shows great liability to injury in the processes of section preparation.

In addition to these characters, however, the tissue of the area postrema is characterised by the presence of nerve-cells, forming, at all events in some cases, a very definite and prominent neuronic group. Retzius has remarked that the area postrema is subject to considerable variation as regards the extent of its development. Neither of the writers I have cited would appear to have recognised the existence of neurones in this tissue, which they seem to regard as merely vascular. I have found considerable variation as to the relative abundance of the nerve-cells, but I have never found them entirely absent. And, in several of the series of microscopical sections in my possession, I find the neurones present so numerous, and so distinctly localised as a definite group, as to deserve special recognition and designation as a "nucleus postremus."

As already mentioned, the neuroglia system of this nucleus postremus consists of a delicate, loose, and open myelospongium, quite different from that of the tissue surrounding it. From the latter it is somewhat abruptly differentiated, except in the direction of the tænia, into which the transition is a more gradual one. That the distinction of its neuroglia system is a primary one is shown by the fœtal condition reproduced in figs. 21 and 21A, in which the part played by the dorso-lateral neuroglia septum is a very obvious one. From other preparations it would seem that the dorso-lateral limitation of the mass of the nucleus postremus, at least in the adult, is partly conditioned by the entry of blood-vessels. The general vascularity of the nucleus is well illustrated by figs. 23–25. Fig. 28 has previously been referred to as showing the emergence of the area postrema upon the floor of the ventricle. The section from which the photomicrograph was taken was stained with methylene blue. On the right side of the figure

the hypoglossal and vagus nuclei are readily recognisable, whilst the nucleus postremus stands out prominently as a quite sharply defined area, thickly dotted with the bodies of small and medium-sized polymorphic neurones. Perhaps the more prevalent form is flask-shaped or pyriform, often with one large polar dendrite and an axone arising from the opposite pole. Nevertheless, both spheroidal, and more or less triangular, forms also occur. A view of the nucleus as a whole, showing the distribution of the neurones, is seen in fig. 30 from another section of the same specimen.

A reproduction of a high-power photomicrograph of a portion of the nucleus showing a number of the characteristic neurones is given in fig. 38. The section was stained with methylene blue, and the coarsely granular Nissl bodies are apparent in the cytoplasm.

Fig. 39 shows a photomicrograph of a portion of the nucleus postremus from another section stained with iron hæmatoxylin by Benda's method. This figure affords a very clear conception of the histological characters of the nucleus in a case in which the neuronic character is predominant. Other cases occur in which the neurones are far more sparsely distributed. In these the loose myelospongium is traversed by numerous blood-vessels which are frequently distinguished by a specially thick-walled character.

I have not thus far been able to make any special investigation of the paths followed by the axones of this group of neurones. I have, however, seen numbers of fibres apparently proceeding from the nucleus at its dorso-lateral angle, and appearing to turn dorsally into the roof in the neighbourhood of the ponticulus which contains many medullated fibres. But I cannot at present certainly identify these fibres with the axones of the neurones of the nucleus postremus.

The earlier literature of the microscopical anatomy of the region under consideration is not wholly devoid of the suggestion that the nervous character of this interesting structure has previously been recognised.

In Henle's *Nervenlehre* the prominence of the area postrema is indicated in fig. 123 by the reference letters Ac^1, and the following statement occurs in the neighbouring text (p. 207): "Die Gefässhaut, die den Obex einhüllt, sendet zuweilen längs dem vorderen Rande der Clava einen Fortsatz ins Innere des verlängerten Marks, nach dessen Entfernung eine tiefe Rinne zurückbleibt, welche Clava und Ala cinerea scheidet; in anderen Fällen schiebt sich zwischen beide ein schmales rhombisches Leistchen ein, welches aus der Medianfurche hervorläuft und dem vorderen Rande der Clava folgt, der Accessoriuskern Stilling's (Ac^1)." And, in a footnote to this reference to the "Accessoriuskern," Henle adds, "Die graugelbliche kolbenförmige Substanz *Bergmann*."

I have not, so far, been able to consult Stilling's description and figures,

but it is possible that in naming the small mass of tissue in question "Accessoriuskern," Stilling was aware of its nerve-cellular character. If this be so, the fact has, so far as I know, been entirely overlooked since Henle's reference quoted above. In any case, no descriptive account of it has ever found its way into modern neurological literature.

In figures of cross-sections through the corresponding region of the brain of the rabbit, Van Gehuchten (1900, figs. 374 and 377) does actually represent a markedly prominent mass, apparently containing numerous small nerve-cells. This mass is, without doubt, the homologue of the nucleus postremus described in this paper. No reference is made to it by Van Gehuchten, either in the text or in the explanation of the figures. From a neighbouring figure (fig. 376) one is enabled to infer that the prominences of opposite sides become confluent with one another at, or just below, the point corresponding to the calamus scriptorius. This median coalescence is obviously the same as that which has been above described as taking place in the human subject in varying degrees.

§ XII. Summary.

1. The ordinarily current descriptions of the neural canal of the bulb, immediately below, and at, its transition into the cavity of the fourth ventricle, are incomplete and more or less discrepant. There is also a lack of adequate pictorial illustration of the sectional anatomy of the region.

2. Henle gave a tolerably detailed account of the structural conditions met with in the region in question. He recognised the occurrence of certain variations, which he attempted to classify. Henle's description was, however, vitiated more or less by the lack of precise knowledge of the structure and relations of the roof of the neural canal at and in the vicinity of the calamus scriptorius. This deficiency is attributable to the imperfect methods of sectional investigation at his command.

3. Our knowledge of the naked-eye anatomy of this locality has been amplified by Retzius, who has also noted certain variations in structure.

4. Blake also made an important contribution, in his investigations regarding the occurrence of a caudal evagination or protrusion, as a feature of the development of the mammalian rhombencephalon.

5. The more or less imperfect representative, in the human adult subject, of Blake's "caudal protrusion," is commonly recognisable. It extends dorsally to the obex, and a remnant of its pia-ependymal wall is reflected from the dorsal surface of the caudal extremity of the obex.

6. The obex is essentially a modification of the roof-plate of the neural canal, situated immediately behind the site of the caudal evagination of

the thinned-out roof of the rhombencephalon. As Blake has pointed out, it represents the dorso-median structural continuity of the "secondary rhomboidal lips" of His.

7. Two forms of obex are met with in the human adult: (*a*) the "true obex" is constituted by a medullary thickening of the roof-plate in the site indicated, where the secondary rhomboidal lips of opposite sides are continuous; (*b*) a "false" or membranous obex is met with in cases in which the medullary thickening fails to take place. The roof-plate is then represented only by the ependymal layer, clothing the ventral surface of a pial reduplication which forms the main substance of the membranous fold in question. Here the pial reduplication reaches the anterior free border of the "false obex." Where a "true obex" is present, on the other hand, the pia does not extend forwards to its anterior border, but is reflected (along with a layer of ependymal epithelium) from the dorsal aspect of the caudal extremity of the obex.

8. The characters of the lumen of the central canal of the bulb near its entry into the fourth ventricle are prone to variation.

9. Staderini has given a substantially correct descriptive account of the structural changes met with (in typical cases) during the transition from the central to the fourth ventricle. His account, however, fails to convey any adequate idea of the real nature of the processes involved; and he does not appear to have recognised the existence of an important class of atypica cases possessing widely different features.

10. In typical cases the central canal of the bulb, immediately below its entrance into the fourth ventricle, retains the typical embryonic form described and figured by His as existing in the fœtal spinal canal. It is cleft-like in form, and its lateral walls are marked by two sulci, dorso- and ventro-lateral.

11. The narrower dorsal portion of the cleft-like lumen becomes obliterated lower down, in consequence of a coalescence of its walls, determined by the close apposition of the dorsal white columns. The preservation of the dorsal cleft in the region immediately below the calamus is accounted for by the "divergence of the clavæ" and the consequent removal of the hampering influence of the dorsal columns.

12. The two lateral sulci of the central canal limit three longitudinal zones. These are continuous with the three areas of the lower part of the floor of the ventricle, viz., area postrema, ala cinerea, and area or funiculus hypoglossi. These correspond to the three longitudinal zones constantly recognised in the rhombencephalon of lower vertebrates by v. Kupffer. The area postrema of Retzius represents the true dorsal zone of the embryonic canal in this region. It is specially prominent in the fœtal bulb. It is

impossible to trace these three zones of the central bulbar canal caudally beyond a very short distance, on account of the appearance, in that direction, of a process of median coalescence of the opposing walls of the canal.

13. The extent of median fusion of the walls of the cleft-like canal of the bulb is subject to variation in degree, as well as regards the precise areas affected by the fusion process. In typical cases there is an entire absence of coalescence in the vestibular region lying immediately below its opening into the ventricle.

14. The coalescence ordinarily first appears in the dorsal zone, *i.e.* in that portion of the lumen whose walls are formed by the areæ postremæ giving rise to "interpostremal coalescence." This may set in at varying levels. If it occur specially high up, the coalesced interpostremal mass may also become continuous with the roof-obex overlying it. If such an incorporation of the overlying roof-plate do not occur, then a "supra-postremal recess" between them will remain.

15. The process of median coalescence of the walls of the canal may, however, first affect the intermediate zones of these walls, leaving the dorsal zone at that level free from median fusion. When this occurs, an intercinereal commissural connection is established between the cinereal funiculi of opposite sides. This commissural connection may occur as high as the junction of the central canal with the fourth ventricle. It then occasions the appearance of two central canals, ventral and dorsal, both opening into the ventricular cavity. The latter constitutes a "supra-commissural recess."

16. The "funiculus separans" of Retzius is a mere ependymal strip or stria. The appearance of a median fusion of these "funiculi," noted by Retzius, is in reality due to the development of an intercinereal commissure, which may involve the "funiculi separantes."

17. The prominence of the area postrema is seen on section to be occupied by a myelospongium of specially loose and delicate character. It is richly vascularised; and is also characterised by the presence of neurones of moderate size. These are always present, and, in what may probably be regarded as the typical cases, the neurones are very abundant throughout the mass of tissue corresponding to the area postrema. This mass of tissue is pretty sharply marked off from the surrounding tissue by a neuroglia septum as well as by conspicuous differences in histological character, and the neurones occupying it form a very well-defined group which may therefore be distinguished as a "nucleus postremus."

18. The structural connections of the neurones of the nucleus postremus have not, thus far, been ascertained.

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EXPLANATION OF FIGS. 21A–38.

Fig. 21A (× 104).—Here a portion of the field of fig. 21 is shown under higher magnification. The characters of the ependyma are well illustrated. At the bottom of the dorso-lateral sulcus is a group of much elongated ependyma cells whose deep extremities are prolonged as a leash of fibrils forming a very well-marked ependymal neuroglia septum. This constitutes a fairly definite ventro-lateral boundary for the tissue of the nucleus postremus, limiting it off from the cellular systems in its neighbourhood. The flattened ependymal epithelium clothing the free surface of the area postrema is visible only here and there, though it was actually present over the entire surface. The stain employed (the section was an old brown Weigert preparation) was not adapted to bring out the neurones of the nucleus postremus.

Fig. 22 (× 4).—Stereograph of dorsal aspect of specimen vi. (*cf.* figs. 12–14), after removal of the ventricular roof, but with the false or membranous obex still *in situ*. The funiculus hypoglossi is well seen. Its surface shows the characteristic marking which gave rise to Retzius's description of an "area plumiformis."

Fig. 23 (× 24).—From a transverse section through the lower part of the fourth ventricle of the adult human specimen which is shown in the stereographs in figs. 12–14 and 22 (*cf.* esp. fig. 14). The plane of the section lies above (cephalad of) the "intercinereal commissure." The dorso- and ventro-lateral sulci are well marked. Note the peculiarly loose and vascular character of the stroma of the nucleus postremus.

Fig. 24 (× 24).—From a section about 0·4 mm. behind the plane of fig. 23. It passes through the frontal edge of the "intercinereal commissure." The ventro-lateral sulcus is still visible on each side, limiting ventrally the more dorsal wider portion of the cleft-like lumen. In other words, the cinereal funiculi are not yet completely fused across the median plane. The dorsal surface of the intercinereal commissure forms the floor of the supracommissural recess of the ventricle (*cf.* fig. 14). The roof of this recess is destroyed, but its lateral attachments are discernible at the dorso-lateral angles of the postremal masses. The roof is seen *in situ* in fig. 22, where it is formed of the false or membranous obex.

Fig. 25 (× 24).—From a section about 0·4 mm. further in a caudal direction from plane of fig. 24. The intercinereal commissure now extends dorso-ventrally the whole way from the dorso-lateral to the level of the ventro-lateral sulcus. The latter is no longer apparent as such. The "supracommissural recess" has considerably narrowed.

Fig. 26 (× 24).—From a section about 0·7 mm. behind plane of fig. 25. The clavæ have largely approximated to one another dorsally, and thus the dorsal portion of the ventricular cavity, above the horizontal plane of the dorso-lateral sulci, has become laterally compressed. In this way the dorso-ventral extent of the cleft-like canal ventricular cleft is greatly increased. The postremal masses now lie in the lateral walls of the dorsal portion of the cleft-like lumen. An inflexed marginal remnant of the roof-plate is visible on the left side of the figure. Ventrally the posterior limit of the intercinereal commissure is just grazed in the section. An oblique line joining the lumina of the two large blood-vessels passes through this commissural remnant. Dorsally from this, and just about the level of the dorso-lateral sulci (no longer distinguishable as such), there is seen an additional slight median fusion. This is continuous, frontally, with the dorso-caudal angle of the intercinereal commissure; but it is to be regarded as constituting the most anterior portion of the commencing interpostremal coalescence.

Fig. 27 (× 24).—From a section about 0·1 mm. behind the plane of fig. 26. The roof-plate (forming a rudimentary true obex at the caudal extremity of the membranous or false obex present in this specimen vi.) is now practically complete. The intercinereal commissure has disappeared entirely from the ventral part of the canal; but its more dorsal backward continuation has increased in thickness and is beginning to involve the neighbouring parts of the postremal masses in a median fusion.

Fig. 28 (× 24).—From a section about 0·1 mm. behind the plane of fig. 27 (the section is reversed as compared with figs. 26 and 27). The dorsal portion of the cleft-like canal has undergone a sudden, well-nigh complete obliteration from interpostremal coalescence. Traces of lumen in this region may, however, be

detected here and there. The ventral portion of the coalesced area is in series with the dorsal part of the intercinereal commissure further forwards, and is probably not properly interpostremal.

The roof-plate is no longer distinguishable as such, being fused with the coalesced postremal tissue to form a common, dorsal, grey commissural mass.

Fig. 30 (× 125).—Photomicrograph of section across the area postrema, to show the general histological characters of the nucleus postremus. The mass is bounded ventrally by the dorso-lateral sulcus and the ependymal neuroglia septum prolonged therefrom. Its free surface is covered by a distinct layer of flattened ependyma cells. The section was stained with Benda's iron-hæmatoxylin.

Fig. 31 (× 4).—Stereograph of calamus region, etc., of another adult human bulb (specimen viii.), showing a typical and uncomplicated central canal opening into the fourth ventricle under cover of an obex which is at least mainly membranous. The specimen was not sectioned, hence it is impossible to say whether or not the obex was wholly membranous.

The prolongation of the cinereal funiculus into the lateral wall of the central canal is very obvious. The "funiculus separans" is evident in the form of a slender stria skirting and overlapping the dorsal part of the surface of the cinereal funiculus.

Fig. 32 (× 4).—Stereograph showing floor of ventricle and calamus region of another fœtal human medulla oblongata which exhibits the "typical" arrangement. The funiculus separans is seen as an insignificant white stria parallel with, and close to, the dorsal border of the funiculus cinereus, and just ventral to the dorso-lateral sulcus.

Fig. 33 (× 4).—Stereograph showing dorsal view of bulb, etc., of a human fœtus. The whole of the membranes, with the pia-ependymal roof of the fourth ventricle, have been removed. Between the diverging clavæ, and more or less parallel with them, are seen the areæ postremæ. Caudally, these are seen to meet in an interpostremal fusion which simulates an obex. In reality the true roof-plate, with any obex-structure which may have been present, had been removed with the membranes. The medially fused tissue is simply interpostremal, as the series of sectional figs. 34–36 clearly show. In fact the dorsal aspect of the medially fused postremal mass formed the floor of a "suprapostremal recess."

Fig. 34 (× 30).—From a section across the fœtal bulb shown in fig. 32. Here the postremal masses have pretty closely approximated to one another. The dorso- and ventro-lateral sulci show their characteristic form. They limit the three columnar elevations of the ventricular walls. The abrupt change in the character of the ventricular ependyma at the level of the dorso-lateral sulci is to be noted. The flattened ependymal epithelium can easily be followed over the surface of the area postrema to the point where the thin pia-ependymal roof had been torn away from its lateral attachments to the dorso-lateral angles of the postremal masses.

Fig. 35 (× 30).—From a section a short distance caudal to the plane of fig. 33. The gradual narrowing of the ventricular cleft is apparent. Dorsally, however, the cavity had still extended widely in a horizontal direction beneath the thin pia-ependymal roof which is lacking in the section.

Fig. 36 (× 30).—From a section through a still more caudal plane than that of fig. 35. The postremal masses of opposite sides have been brought in contact through the continued narrowing of the dorsal region of the ventricular cleft, and have now effected a partial coalescence across the median plane. It is to be noted, however, that a triangular, ependyma-lined, "suprapostremal recess" had still been in existence dorsal of the area of interpostremal coalescence.

Fig. 37 (× 30).—In this still more posterior plane, the interpostremal fusion is practically complete. A mere remnant of the ependyma-lined recess is visible dorsally.

Fig. 38 (× 600).—High-power photomicrograph of a small portion of the nucleus postremus to show the characters of its constituent neurones. The preparation was stained in methylene blue.

Fig. 39 (× 350).—Portion of a section stained with Benda's iron-hæmatoxylin, to show the neurones and the general structure of the nucleus postremus.

Fig. 21a.

A

B

Fig. 22.

Fig. 23.

Fig. 24.

Fig. 25.

Fig. 26

Fig. 27.

Fig. 28.

Fig. 30.

A FIG. 31. B

A FIG. 32. B

A FIG. 33. B

Fig. 34.

Fig. 35.

Fig. 36.

Fig. 39.

Fig. 37.

Fig. 38.

SUPERNUMERARY LIMB IN A FROG. By JAMES F. GEMMILL, M.A., M.D.

DESCRIPTION.

THE specimen to which the following paper has reference was kindly given to me by Mr G. H. Cockburn, and is a female of *Rana temporaria*, half grown.

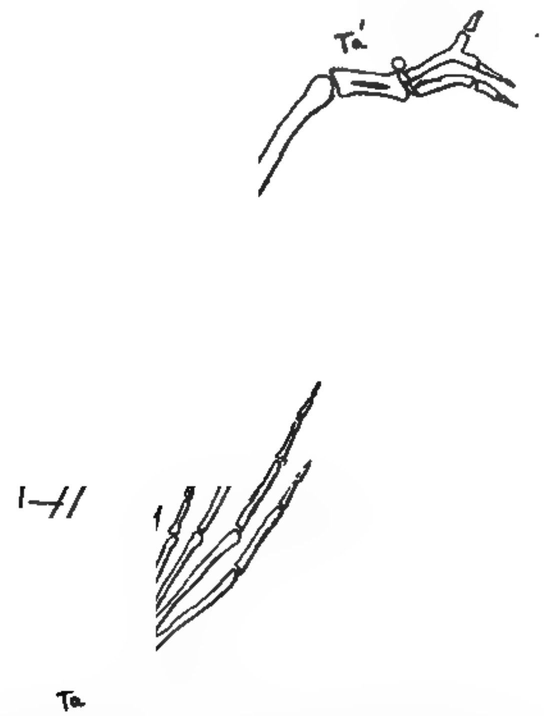

FIG. 1.—Skeleton of right hind-leg, seen from behind, with supernumerary limb attached. F, T, *Ta*, the normal femur, tibia, and tarsus respectively ; F', T', *Ta'*, the supernumerary femur, tibia, and tarsus. The shafts of the femora are partly united.

The right thigh is thicker than normal, and carries at the knee joint a supernumerary leg with distinct tibial, tarsal, and digital regions. The

supernumerary leg articulates by a synovial joint with an extra femoral condyle in such a way that when fully flexed it lies against the inner aspect of the right thigh.

The pelvis is slightly distorted, but contains no elements additional to the normal pubic, ischial, and iliac bones. The right acetabular cavity is transversely elongated, and has two shallow depressions for articulation with the femur. The femur is double at its proximal and distal ends, while the shaft consists of two pieces united together along their inner surfaces. The condyles at the lower end carry articular surfaces for the tibiæ of the normal and of the supernumerary limb. The tibia of the latter is slender and slightly shorter than normal; the tarsus consists of astragalus and calcaneum united together; of the digits only three are present, each containing one or two distorted phalanges (fig. 1).

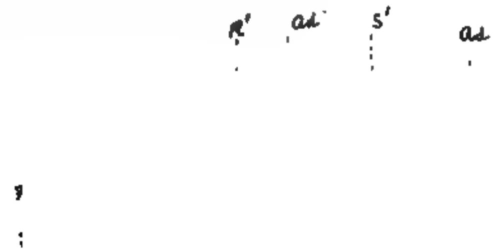

Fig. 2.—Muscles, etc., on inner aspect of composite right thigh. T, T′, normal and supernumerary tibiæ; F, F′, normal and supernumerary femoral condyles; R, R′, normal and supernumerary rectus internus muscles; S, S′, normal and supernumerary semitendinosus muscles; Sp., the common perforating head of the two semitendinosus muscles; St., St′., tendon of normal and supernumerary semitendinosus muscles; Ad., the large common adductor muscle.

Muscles.—The right thigh contains, (1) in relation with the normal leg, a set of muscles which is complete except for the absence of the vastus internus and sartorius, (2) in relation with the supernumerary leg, a reduced set of muscles grouped together on the inner aspect of the thigh, between the normal rectus anticus and the rectus internus. This set consists of rectus internus major and minor, semitendinosus and iliacus. The adductor magnus is attached to both femoral shafts, and the common extensor tendon divides into two at the knee, one slip going to the normal tibia and the other to the tibia of the supernumerary leg. The normal and

the accessory semitendinosus have a common perforating head of origin. In the supernumerary leg, gastrocnemius, peroneus, tibialis anticus, and tibialis posticus can be recognised as fibrous bands containing a small amount of muscular tissue.

Nerves.—In the sacral plexus the seventh and eighth spinal nerves on the right side are enlarged, and the seventh, after giving off the ilio-hypogastric branch, receives an unusually large accession of fibres from the eighth. The right crural nerve thus formed has the following distribution: (1) cutaneous branches to skin of thigh, (2) branches to such of the normal thigh muscles as are usually innervated by the crural, (3) branches to all the accessory thigh muscles, (4) a considerable branch which runs down under cover of the accessory sartorius, and reaching the back of the supernumerary leg, becomes its posterior tibial. The vascular supply of the supernumerary leg is derived from the crural vessels.

Classification.

This specimen is best included under "homotopic redundancy," a term introduced by Windle (*Journ. of Anat. and Physiology*, vol. xxviii. p. 25) as covering by far the greater number of those abnormalities of excess which do not depend on duplicity of the embryo. The specimen is intermediate between *ilio-polymelus* and *melo-melus* as defined by Taruffi (*Storia della Teratologia*, vol. iii. pp. 341 and 408), because, while the right limb is completely double only from the knee downwards, there is partial duplicity of the femur and of the soft structures in the thigh right up to the pelvis.

The innervation of the supernumerary leg from the crural nerve may be referred to as being of great interest. It shows that the redundant limb-bud developed in a position proserial to the normal limb. An excellent example of a similar arrangement is quoted by Taruffi from Fabretti and Cavanna (Taruffi, *l.c.*, vol. iv. p. 407). In this case the accessory limb was attached to an extra ilium which stretched from the normal symphysis pubis to the left transverse process of the ninth vertebra.

Owing to its defective development, the supernumerary limb in my specimen is not recognisable externally as either right or left. But the relations of the extra sartorius, gastrocnemius, peroneus, and tibialis muscles to the accessory tibia are those of a left limb. In the thigh the relation of the extra muscles to the normal set shows distinct bilateral symmetry, the extra set being disposed on one side of a middle line as if mirrored from the normal ones. In these respects the secondary symmetry, illustrated so fully by Bateson as occurring in the supernumerary limbs of insects, etc., can be recognised in my specimen.

It will be seen from the tables appended that a complete series can be made out, ranging from cases of polydactylism, through doubling of the foot, to examples of a fully developed accessory limb.

Similarly, a complete series can be made out between accessory single limbs and accessory pairs of limbs. There can be no doubt, I think, that in Amphibia both series may arise through "repetition," independent of duplicity in the embryo. On the other hand, the case recorded by Van Deen, in which, along with bifurcation of the alimentary canal, there was a pair of accessory hind-limbs, can best be explained in terms of original axial duplicity.

Exceedingly few examples of axial duplicity in Amphibia have been recorded beyond those which occur, for the most part artificially, in the ovum or very early embryo. None of them, so far as I know, have been found at an age which would throw light on the origin of accessory limbs. Distinguished from axial duplicity is the *Asyntaxia caudalis* of Roux (*Archiv für Entwickelungs Mechanik*, vol. ix. p. 2), in which, owing to failure of the blastopore to close, two tail-buds, each representing a half tail, may arise. But it would seem that in these cases either the embryo dies, or the double condition rectifies itself through fusion of the two tail-buds or through atrophy of one of them. It is not impossible that even the temporary presence of two tail-buds might supply the blastema necessary for the formation of supernumerary hind-limbs. But this is pure conjecture, and in any case it does not help to explain the quite frequent occurrence of accessory fore-limbs in Amphibia. The same consideration applies to the condition of *cauda bifida*, which, as it has been produced artificially in a number of ways, might possibly occur in nature (Barfurth, "Die experimentelle Herstellung der Cauda bifida bei Amphibienlarven," *Archiv für Entwickelungs Mechanik*, vol. ix. p. 1).

One naturally thinks of supra-regeneration after injury or amputation as being possibly a factor in the production of accessory limbs in Amphibia. But, as a matter of fact, Barfurth's careful series of experiments, done at the earliest stages possible, showed that in the frog there is no supra-regeneration after amputation, all the limbs regenerated being either normal or defective. In the newt, on the other hand, the regenerated limbs frequently had supernumerary digits, while in the Axolotl cases of double foot occurred (*Archiv für Entwickelungs Mechanik*, vol. i. p. 115).

On the whole, the ætiology of supernumerary limbs in the Amphibia seems to be practically unknown at the present time. It is, however, certain, in my opinion, that the vast majority of them, even those in which the supernumerary limbs form a pair, are examples of repetition (homotopic redundancy) and do not depend on duplicity in the embryo. In this respect

the Amphibia differ markedly from the birds and mammals in which the converse rule holds good.

List of Instances previously recorded in Amphibia.

The following tables are as complete as I can make them from the literature at my disposal. In very many cases I have quoted from abstracts given by Taruffi, the original papers not being accessible to me. Where details are available, attention has been paid to whether the supernumerary limbs are single, double, or composite, to the presence or absence of girdle elements connected with them, and to their position with relation to the normal limbs. The list[1] is arranged under the following sections and subsections:—

Section I.—Occurrence of a supernumerary limb which is single and has no additional parts.
- Subsection 1.—Supernumerary limb anterior.
- Subsection 2.—Supernumerary limb posterior.

Section II.—Occurrence of a supernumerary limb which is composite or possesses reduplicated parts.
- Subsection 1.—Supernumerary limb anterior.
- Subsection 2.—Supernumerary limb posterior.

Section III.—Occurrence of a supernumerary pair of limbs.
- Subsection 1.—Supernumerary limbs anterior.
- Subsection 2.—Supernumerary limbs posterior.

To these may be added a short list of cases in which one of the ordinary limbs shows partial duplicity or reduplication of parts.

Section I. Subsection 1.

Supernumerary Anterior Limb, single, and without additional parts.

1.	Hunterian Coll.	Supernumerary limb springs from	posterior and lateral part of sternum.
2.	De Superville.	" "	right shoulder.
3.	Otto.	" "	right scapula (Pelobates fuscus).
4.	D'Alton.	"	adheres to humerus of normal left limb.
5.	Gervais.	"	articulates with an accessory coracoid and scapula attached to the normal left coracoid (Pelobates cultripes).
6.	Strobel.	"	arises to left of middle line at boundary, between thorax and abdomen.

1. Quoted from Bland Sutton, *Evolution and Disease*, p. 111.
2, 3, 4, 5. Quoted from Taruffi, *Storia della Teratologia*, vol. iv. p. 325, Oss. 12, 13, 14, 15.
6. " " " " vol. iii. p. 241, Oss. 10.

[1] Unless where otherwise indicated, the records have reference to one or other of the species of *Rana*.

7. Bland Sutton. Supernumerary limb is attached to anterior part of left moiety of shoulder girdle by what seems to be an accessory coracoid.
8. Johnson. ,, arises from the left and one also from the right scapular region.
9. Bergendal. ,, is attached to outer part of right coracoid ventrally and anteriorly.

Section I. Subsection 2.

Supernumerary Posterior Limb, single, and without additional parts.

11. Balsamo Crivelli. Supernumerary limb is attached close to symphysis pubis on left side.
12. Fabretti. ,, ,, as above.
13. Strobel. ,, is close in front of right limb; has a common acetabular cavity with right femur, and is enclosed in the same skin to half-way down the thigh.
14. Ercolani. ,, hangs between the normal ones and has an acetabular cavity on the pubis.
15. Parona. ,, is a stump inserted into superior border of pubic symphysis.
16. ,, ,, is attached to the posterior inferior tuberosity of the ilium.
17. ,, ,, is to inside of right limb, and has a common covering of skin to middle of thigh and common acetabular cavity with right limb.
18. Otto. ,, is inserted on right side of pelvis.
19. Vallisneri. ,, arises from right side of coccyx. (The left limb has seven toes.)
20. Fabretti. ,, is on left side and articulates with an accessory ilium, almost regular in form, which stretches obliquely from the margin of the symphysis pubis to the transverse process of the ninth vertebra.
21. Strobel. ,, is attached above left hip-joint, probably on internal aspect of ilium.
22. ,, ,, ,, to left of anus.
23. Cisternas. ,, ,, on left side of pelvis (Alytes obstetricans).

7. *Evolution and Disease*, p. 112.
8. *American Naturalist*, vol. xxxv. pt. 1, 1901.
9. *Bihang Kong. Svenska Vet. Ak. Handlingar*, 1888, Bd. 14, Afd. iv., No. 8.
11, 12, 13, 14, 15. Taruffi, *l.c.*, vol. iv. p. 402, Oss. 27, 29, 30, 33, 34.
16, 17, 18 ,, ,, p. 406, Oss. 18, 19, 15.
19. ,, ,, p. 422, Oss. 101.
20, 21, 23. Taruffi, *l.c.*, vol. iv. pp. 407–8, Oss. 20, 21, 24.
22. ,, ,, pp. 422–3, Oss. 102, 105, 106.

24. Sordelli. Supernumerary limb hangs between left normal limb and anus.

25. Thomas. ,, is attached between sacrum and hip-joint, is slender, and has syndactylous digits (Bufo vulgaris).

26. Tuckerman. ,, is attached a little to left of posterior end of urostyle.

27. Kingsley. ,, arises below and a little to left of vent; articulates with an acetabulum on the symphysis pubis.

28. Alessandrini. ,, is misshapen and arises from centre of abdomen in middle line.

29. Guittard. ,, arises from abdomen in front of left hind limb.

Section II. Subsection I.

Supernumerary Anterior Limb, composite, or with additional parts.

30. Cavanna. Supernumerary limb has single coracoid scapula and humerus; the forearm is composite, having two ulnæ and a median radius; metacarpals are partly doubled and partly awanting.

31. Bassi. ,, is placed just behind the normal right limb, to which it is united by a muscular and fibrous band; has five toes, the supernumerary one being imperfect.

32. Eigenman and Cox. ,, is on ventral side of normal right limb; has five toes.

Section II. Subsection 2.

Supernumerary Posterior Limb, composite, or with additional parts.

33. Ercolani. Supernumerary limb has a single femur, two tibiæ enclosed in common integument, two separate tarsi and sets of phalanges. The accessory femur lies alongside the normal right femur in a common integument sheath.

24, 25. Taruffi, *l.c.*, pp. 422–3, Oss. 102, 105, 106.
26. *Journ. of Anat. and Physiology*, vol. xx. p. 516.
27. *Proc. Boston Soc. Nat. Hist.*, vol. xxi. pp. 169, 173.
28, 29. Taruffi, *l.c.*, vol. iii. pp. 240, 529.
30, 31. Taruffi, *l.c.*, vol. iv. p. 327, Oss. 19, 17.
32. *American Naturalist*, Jan. 1901, p. 33.
33. Taruffi, *l.c.*, vol. iv. p. 403, Oss. 32; p. 408, Oss. 22.

34. Strobel.	Supernumerary limb has	one femur, but is double from knee downwards; the supernumerary femur enclosed in same integument as normal right thigh.
35. Johnson.	,,	arises directly above the hind-leg, is attached to ilium, which is bifid posteriorly; distal end of tibia fibula has three enlargements; three bones replace astragalus and calcaneum; eight metatarsals.
36. Ryder.	,,	bears evidence that it was formed by the fusion of two by their inner surfaces.
37. Strobel.	,,	is inserted posteriorly between right flank and anus, has no femur, but the lower part is doubled and has seven toes.
38. Parona.	,,	has femur attached to posterior inferior tuberosity of left ilium; nine toes present.
39. Dumeril.	,,	is very slender, without femur, but with six metatarsals and six toes.
40. Bland Sutton.	,,	has seven toes.

Section III. Subsection 1.

Pair of Supernumerary Anterior Limbs present.

41. Lunel.	Supernumerary pair	of limbs	are placed to outside of normal left limb on two fused accessory scapulæ.
42. Sordelli.	,,	,,	lie behind the normal left limb.
43. Ercolani.	,,	,,	lie above the normal left limb on two fused accessory scapulæ.
44. ,,	,,	,,	do. do.
45. ,,	,,	,,	are on left side; impossible to say which of the three limbs on the left side represents the normal one; scapula on left side single, but connected with two pairs of clavicles and coracoids on that side.
46. Johnson.	,,	,,	arises from a peduncle directly ventral to the right fore-leg.

34. Taruffi, *l.c.*, vol. iv. p. 403, Oss. 32; p. 408, Oss. 22.
35. *American Naturalist*, vol. xxxv. pt. 1, 1901.
36. Quoted by Kingsley in *Proc. Boston Soc. Nat. Hist.*, vol. xxi., 1880–2, p. 173.
37, 38, 39. Taruffi, *l.c.*, vol. iv. p. 422, Oss. 103; p. 408, 23; p. 407, 17.
40. *Evolution and Disease*, p. 110.
41–45. Taruffi, *l.c.* vol. iv. pp. 327–328, Oss. 16, 18, 20, 21, 22.
46. *American Naturalist*, vol. xxxv. pt. 1, 1901.

SECTION III. SUBSECTION 2.

Pair of Supernumerary Posterior Limbs present.

48. Van Deen. Supernumerary pair of limbs articulate with a rudimentary pelvis attached to left of normal pubis. This specimen is exceedingly interesting, since, as is stated by Bland Sutton (*Evolution and Disease*, p. 126) the termination of the alimentary canal is bifurcated.

49. Van der Hoeven. ,, ,, are attached to the symphysis pubis.

50. Dumeril. ,, ,, articulate by means of two cotyloid cavities with a rudimentary accessory pelvis attached to the normal pubis.

51. Cavanna. ,, ,, resembles above.

52. Lunel. ,, ,, are enclosed in common integument down to the middle of the tibiæ; articulate by two small cotyloid cavities with a rudimentary pelvis which is attached in front and to the left of the normal one.

53. Cavanna. ,, ,, are attached to a rudimentary pelvis placed above and a little to the left of the anus.

Partial Duplicity of One Limb.

54. Sordelli. A second leg is inserted into the right humerus: is short, slender, and has only three toes (Axolotl).

55. Otto. A second leg arises from inner side of right normal one and is inserted apparently into the normal femur.

56. Camerano. Femur on left side, at a distance of 3 m. from its head, divides into two short branches, each of which carries a surface for articulation with a corresponding leg (Triton tæniatus).

57. Ercolani. Left hind-foot is doubled, each division carrying five toes. The two feet thus formed seemed to be right and left ones.

58. Barfurth. Instances in which double feet were sometimes produced by regeneration after experimental amputation.

Cases of simple polydactyly are not tabulated here.

48–51. Taruffi, *l.c.*, vol. iv. p. 401 *et seq.*, Oss. 25, 26, 28, 31.
52. ,, ,, p. 406 ,, Oss. 16.
53. ,, ,, p. 422 ,, Oss. 104.
54–57. Taruffi, *l.c.*, vol. iii. p. 414, Oss. 9; p. 413, Oss. 7, 8; p. 422, Oss. 12.
58. *Archiv für Entwickelungs Mechanik*, vol. i. pp. 104, 105.

NOTES ON (*a*) THE ORIGIN OF ELASTIC FIBRES IN TENDON, (*b*) BRANCHING OF YOUNG TENDON CELLS. By JAMES F. GEMMILL, M.A., M.D.

(*a*) ON THE ORIGIN OF ELASTIC FIBRES IN TENDON.

THE following note supports the view that elastic fibres originate from cells, and shows that a considerable number of cells may take part in the formation of the fibrillæ from which a single fibre arises.

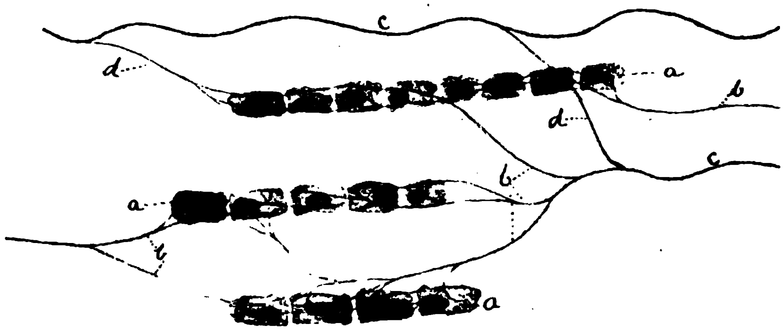

FIG. 1.—From a gold-chloride, formic-acid preparation of tendon from the gastrocnemius of a puppy four months old ; the fibres have been teased apart and mounted in glycerine jelly. *a*, cell-rows with fine network of elastic fibrils on their surface ; *b*, root fibrils of an elastic fibre ; *c*, fully formed elastic fibres ; *d*, connecting branches.

In a series of gold-chloride, formic-acid preparations of tendon from the gastrocnemius of a puppy, I obtained some curious selective variations in the action of the gold. At certain parts only tendon cells, at others only elastic fibres were brought into prominence. At places of transition between two such regions, the cells and the fibres were more faintly stained, but in addition a fine system of fibrillæ of origin for such elastic fibres as happened to arise in these regions was here and there picked out. These fibrillæ are illustrated in fig. 1. They form an elongated network in the surface layers of the rows of tendon cells. They are connected sparingly by fine oblique branches with corresponding networks in adjacent cell-rows. An elastic fibre begins usually in one main root, derived from the union of a number

of fibrillæ arising from the surface of several cells in a cell-row. Other roots additional to the main one are, however, almost always present. They may be derived from the fibrillar network on another part of the same cell-row, or from the similar network on adjacent cell-rows. Any part of a network may give origin to root fibres, either upwards or downwards in the tendon, or to oblique branches which unite with neighbouring fibres. The fully developed elastic fibres may run on or near the surface, or in the substance of the tendon fibres, but of course the growing ends are always superficial. In transverse sections, the elastic fibres appear as dots scattered throughout the ground substance and most numerous close to the cell-rows (fig. 2). I have not been able to find that the fibrillar stage is preceded by one in which the elastic substance is in the form of discrete particles.

The cellular origin of elastic fibres has now been demonstrated for a considerable number of tissues. In elastic cartilage Oscar Hertwig (1) found that the fibres are formed on the surface of the protoplasm immediately after the first appearance of the intercellular substance or simultaneously with it, while Ranvier (2) and Deutschmann (3) confirmed this observation, and added that the elastic substance is laid down first in the form of fine discrete particles which coalesce in rows to form the fibrils. Other workers on the same subject are Reinke (4), Gerlach (5), Spuler (6), and Hansen (7). The tissue investigated by Hansen was fibro-cartilage from the intervertebral discs of calf fœtuses. In the connective tissue cell during its actively formative stage, Hansen distinguishes an outer layer of ectoplasm which is of higher refractive power than the inner protoplasm. According to him, this ectoplasm is the common parent alike of connective tissue and of elastic fibres. As the outer layer becomes converted into fibres, new ectoplasm is formed underneath it, and thus the cell may retain the power of producing new fibres and of adding to their size for a relatively long period. Hansen's results were accepted and extended by W. Flemming (8). Apart from cartilage, the cellular origin of elastic fibre in other tissues has been affirmed by Gardner (9), Teuffel (10), and Taddei Aiuto (11). In the amnion, Gardner states that elastic fibrils do not arise from the extra-protoplasmic substance, but on the periphery of single cells or along anastomosing cell processes, in the form of fine round particles which coalesce in rows. The first fibrils may unite to form thicker ones. Similar results were obtained for the elastic fibrils in the lung by E. Teuffel (10), and in cicatricial tissue by Taddei Aiuto (11).

The occurrence of abundant elastic fibres in tendon and ligament has been demonstrated by Martinotti (12) and Smirnow (13), among others. I have confirmed or extended their observations in the case of the following structures in the human subject: *tendo Achillis*, tendons of *biceps flex.*

cruris, flex. long. dig. (ped.), tibialis posticus, semimembranosus, quadriceps extensor cruris, peroneus longus, flex. prof. dig., extensor carp. rad. brev., extensor long. dig. ped., round ligament of hip-joint, long and short plantar ligaments, transverse ligament of ankle, external lateral and posterior crucial ligaments of knee, semilunar cartilages of knee, ligamentum patellæ, intervertebral discs, interosseous membrane of forearm. Of the tendons I examined, that of the peroneus longus had the greatest number of elastic fibres. Next came the tendons of the tibialis posticus, the flexor longus digitorum, and the extensor carpi radialis brevior. The fewest and slenderest elastic fibres were found in the extensor longus digitorum pedis. No doubt these differences are related to function. The absence of any special supporting or resistant action on the part of the long extensor of the toes immediately suggests itself as connected with its dearth of elastic fibres, in contrast, say, to the peroneus longus.

Of the ligaments I examined, the long and short plantar ligaments, and the interosseous membrane of the forearm, had the greatest number of elastic fibres. In general, elastic fibres are stronger and more numerous, and they branch and anastomose more freely in ligament than in tendon.

(*b*) Branching of Young Tendon Cells.

Tendon cells are usually described as occurring in rows in the spaces between adjacent tendon fibres, the cell bodies occupying the middle of

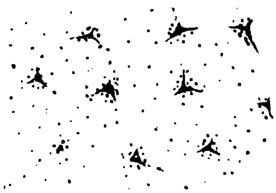

Fig. 2.—Transverse section of part of gastrocnemius similarly stained; glycerine jelly mount; elastic fibres showing as dots throughout the substance of the fibres, but most numerous close to the cells.

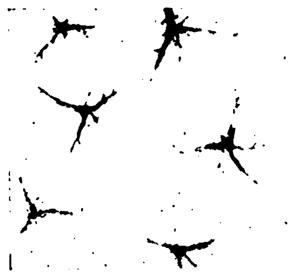

Fig. 3.—Transverse section from gastrocnemius of tendon of puppy showing numerous delicate, sometimes branched processes on the cell bodies and lamellæ. (Gold-chloride formic-acid preparation.)

these spaces and sending smooth, flattened lamellæ outwards between the tendon fibres. The occurrence of fine branches on the cell bodies and lamellæ is indicated in the following note.

In sections of tendon (from a puppy four months after birth) which had been macerated very slowly in formic acid and treated with chloride of gold, I found a considerable number of delicate processes sticking out vertically from the cell bodies and lamellæ, and penetrating the substance of the tendon fibres. The appearance of a group of cells from a transverse section of the gastrocnemius is illustrated in fig. 2. No doubt the fine branches serve for the nutrition and growth of the tendon fibres. As stated above, the tissue is taken from a young animal. At the same time it is old enough to present all the other histological appearances typical of adult tendon.

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(1) O. Hertwig, *Archiv für mikroskop. Anatomie*, IX. p. 180, and XI., supplement.

(2–6) Quoted from W. Flemming in *Handbuch der vergleichenden und experimentellen Entwickelungslehre der Wirbelthieren*, V. Lief., C. iii., pp. 10 to 16.

(7) Hansen, *Anatomischer Anzeiger*, 1899, XVI. p. 417.

(8) Flemming, reference as under (2–6).

(9) Gardner, *Biologisches Centralblatt*, vol. xvii. p. 406.

(10) Teuffel, *Archiv für Anatomie und Physiologie*, Anat. Abth. 1902, p. 377.

(11) Taddei Aiuto, quoted from *Jahresbericht über die Leistungen u. Fortschritte in der gesammten Medizin*, 1903, Bd. i. Abth. 2, p. 291.

(12) Martinotti, *Anatomischer Anzeiger*, vol. xvi. p. 201.

(13) Smirnow, *Anatomischer Anzeiger*, vol. xv. p. 484.

ON THE DEVELOPMENT, OSSIFICATION, AND GROWTH OF THE PALATE BONE OF MAN.[1] By EDWARD FAWCETT, M.B. Edin., *Professor of Anatomy, University College, Bristol.*

THROUGH the kindness of Professor Minot of Harvard, I am able to present the result of an investigation on the above subject. I have been fortunate enough to have from him a human embryo of 19 mm. in length, in which the palate bone is just commencing to ossify. I have also from Professor Minot other embryos in which ossification is further advanced, and some material supplied to me by former pupils has enabled me to complete what it is necessary to do by aid of the microscope.

When one looks into the various accounts given by different text-books on the subject, it is, I think, evident that the matter is worthy of further consideration. It is true there is perhaps greater unanimity with regard to the ossification of this palate bone than in the case of many others, but the fact still remains that the accounts are still sufficiently at variance to justify the statement that the matter is by no means settled.

Where the various statements are taken from I cannot say, as no references are given, save in the case of Rambaud and Renault.

Cruveilhier, p. 72, English edition, 1841, says the bone is developed from a single centre of ossification, which appears from the fortieth to the fiftieth day at the point of union of the vertical and horizontal portions and the pyramidal process. During its development the bone appears as it were crushed down, so that the vertical portion is shorter than the horizontal, and there is a marked predominance in the antero-posterior diameter.

Gray, sixteenth edition, says the bone is developed from a single centre which appears about the second month at the angle of junction of the two plates of the bone. From this point ossification spreads inwards to the horizontal plate, downwards into the tuberosity, and upwards into the vertical plate.

Some authorities describe the bone as ossifying from four centres: one for the tuberosity and portion of the vertical plate behind the posterior palative groove; a second for the rest of the vertical and horizontal plates; a third for the orbital, and a fourth for the sphenoidal process (this is

[1] Read before the Anatomical Society, January 19, 1906.

evidently from Rambaud and Renault). In the fœtus the horizontal plate is much longer than the vertical; and even after it is fully ossified, the whole bone is at first remarkable for its shortness.

Gegenbaur (French translation by Charles Julin, 1889), says: De même que le maxillaire supérieur, le palatin apparaît après la huitième semaine; toutefois ses rapports de situation sont un peu différents.

Thomson (*Cunningham's Text-Book of Anatomy*) states that "the palate bones are developed from the ossification of the membrane covering the sides of the oral cavity. According to Rambaud and Renault, two primitive centres appear about the sixth week of fœtal life. From one of these the tuberosity and the part of the vertical plate behind the posterior palative groove is developed; from the other the remainder of the bone is formed, with the exception of the orbital and sphenoidal processes, which are developed from secondary centres that make their appearance somewhat later. Other authorities describe the bone as ossifying from a single centre which appears about the end of the second month in the angle between the vertical and horizontal plates. At birth the bone is much longer in its antero-posterior diameter than in its vertical height, the converse of its typical adult form."

Sappey (fourth edition) says: "Le palatin a pour origine un seul point d'ossification que occupe l'angle de réunion de ses deux portions. La portion horizontale s'accroît plus rapidement et l'emporte d'abord sur la verticale. Plus tard, cette dernière s'allonge un peu; il s'établit alors l'une et l'autre une sorte d'égalité. Lorsque le serins maxillaire s'agrandit, on voit la portion verticale s'allonger aussi et devenir prédominante."

Testut is content with quoting the account given by Rambaud and Renault.

Quain (tenth edition) says the palate bone is ossified from a single centre, which appears in the seventh or eighth week at the angle between its horizontal and vertical parts.

Macalister (p. 239) says the palatine bone is formed in a part of the pterygo-quadrate cartilage, and is very irregular and variable. It ossifies by a single centre which appears at the front of the pyramidal process in the seventh week.

Humphry is very accurate, as a rule, when describing the ossification of a bone. With reference to the palate bone he says (p. 296): "Each palate bone is developed from one nucleus which appears between the fortieth day and the third month, at the angle of union of the horizontal with the vertical portion. The palatine process soon shoots inward to meet that of the opposite side. In the young child the bone has very little depth; the transverse measurement is greater than the vertical, and the orbital portion is not yet formed."

Personal Observations.

Sections of various embryos have been examined, some from my own collection, but many from that of Professor Minot of Harvard.

Examination of coronal sections of a 19 mm. embryo. These were examined and drawn serially, and it will be noticed that the two opposite halves of the palate P. are at this stage vertically disposed at the side of the tongue T., some distance above what might be expected to represent the point where the angle will be formed. Between the side of

Fig. 1.

P.B., palate bone; P.N., palatine nerves; P., palate hanging down by side of tongue, T. Harvard collection, No. 819, sect. 284. Coronal 19 mm. embryo.

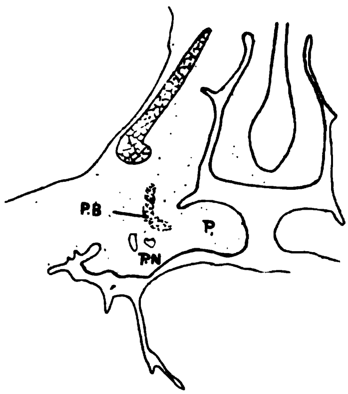

Fig. 2.

P.B., palate bone, just developing palatine process; P., palate, now separating tongue from base of skull; P.N., palatine nerves. Harvard collection, No. 24, sect. 378. Coronal 24 mm. embryo.

the naso-pharynx and the palate, one sees, just commencing to ossify, the palate bone P.B., and it is evident that this centre, as generally described, arises in membrane. Immediately to its outer side can be seen a large nerve clump caused by the palatine nerves. All other sections of this embryo show the same thing, viz., that the palate bone is ossified just internal to the palatine nerves, and therefore in its vertical plate, ossification commencing in the 19 mm. embryo. There is as yet no sign of a horizontal plate.

In an embryo of 24 mm. in length, also supplied by Professor Minot, one sees the two halves of the palate now horizontally disposed, whereas it will have been noticed that they lie vertically disposed by the side of the tongue in the embryo of 19 mm.

It is at this stage that the horizontal plate of the palate bone commences to form, but it does not come off sharply—almost at right angles—as yet; it curves inwards quite at the lower end of the vertical plate, see fig. 2 (Harvard, 24, x. 378). P.B. is the palate bone, P. the palate, P.N. palatine nerves.

At a later stage, however, the direction is much more at right angles to the vertical plate. At no time can any extra centre of ossification be seen. It is true that by making, say, one or two sections either in the horizontal or the vertical direction, one may see what appear to be two

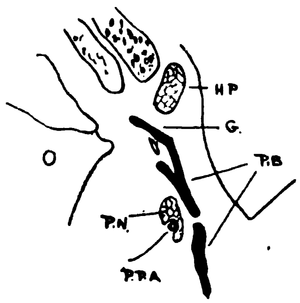

FIG. 3.

P.B., palate bone; G., groove for internal pterygoid plate; H.P., hamular process; P.N., palatine nerves; P.P.A., post-palatine artery. The bone seems here to consist of two separate parts due to foramen.

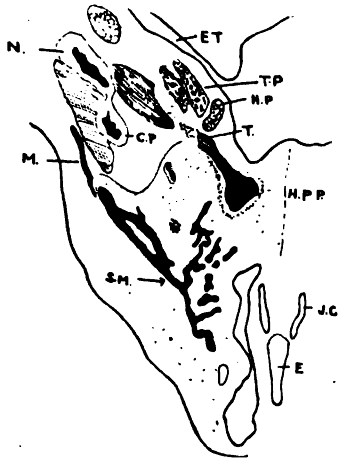

FIG. 3A.

H.P.P., horizontal plate of palate bone; T., tuberosity; H.P., hamular process (cartilaginous); T.P., tensor palati; E.T., Eustachian tube; C.P., coronoid process; N., neck of jaw; M., malar bone; S.M., superior maxilla; E., vertical plate of ethmoid; J.C., Jacobson's cartilage. Own collection, M2. Horizontal 42 mm. embryo.

centres; but that appearance is due, in one region at all events, to perforation of the bone by an artery from the posterior palatine to the inferior meatus and turbinated bone. This foramen seems to be constant, and in early fœtal life is of great size (figs. 3 and 4).

It may be taken as conclusive that there is only one centre for the general mass of the bone. But what about the orbital and sphenoidal processes? are they ossified separately or by extension from the general mass?

Fig. 5 is a representation of a section cut sagittally, which I was lucky to get, and it shows at a very early period all the essential parts of the palate bone. The embryo from which this series of sections was cut was

about 40 mm. in length, but was unfortunately not in the best of preservation and only the bone stained really well, neither nerves nor teeth being stained to any extent. In it one can see the palatine shelf, the maxillary process, and then, quite on the top of the vertical plate, forward and backward projections which indicate the positions of the future orbital and sphenoidal processes. Naturally no spheno-palatine notch is developed, but there is a slight depression on the upper border of the vertical plate which may be taken as representing it (figs. 5 and 6.)

In course of time both the sphenoidal and orbital processes develop as outgrowths from the vertical plate, not by separate ossification, and it is to

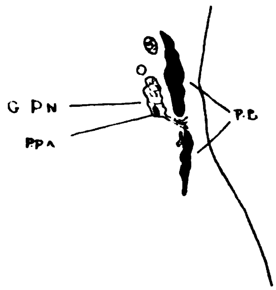

FIG. 4.

P.B., palate bone; G.P.N., great palatine nerve; P.P.A., post-palatine artery. Own collection. Horizontal, above last, 42 mm. embryo.

FIG. 5.

O., orbital process; S., sphenoidal process, T., tuberosity of palate bone; H.P., hamular process; P.M., premaxilla; S.M., superior maxilla; N.C., nasal cavity. Own collection. Sagittal, 40 mm., No. 207.

be remarked that at quite an early stage and until birth even the sphenoidal process is much larger than the orbital one; in fact the orbital process appears not unlike a slender coracoid process of the scapula at this time (fig. 7, *a* and *b*), directed upwards and forwards at first and being largely maxillary in surface; then it turns suddenly upwards and backwards, being mainly orbital. This disparity in size of the two processes is interesting as leading us back to what holds good with the quadruped palate bone. In a specimen three years old the two processes are about equal in bulk, whilst at the sixth the orbital has quite taken the lead.

There is another feature of interest at quite an early stage and continued into childhood, that is, the enormous relative size of the groove for the internal pterygoid plate. In all my specimens from the 42 mm. embryo onwards, this groove is relatively enormous in size (fig. 3, G).

It is a well-known fact that in the fœtal life the antero-posterior extent of the vertical plate is greater than the vertical (fig. 5).

These are the leading features of the ossification and growth of the palate bone put somewhat discursively. I will now put them a little more concisely.

1. The palate bone is developed by membranous ossification taking place at the side of the nasal cavity and immediately internal to the palatine nerves. There is no pterygo-quadrate cartilage in man, so it cannot ossify in that.

2. Ossification commences in the vertical plate in embryos of some 19 mm. in length.

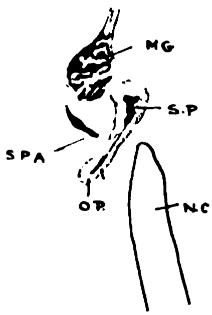

FIG. 6.

S.P., sphenoidal; O.P., orbital process of palate bone; M.G., Merkel's ganglion; S.P.A., spheno - palatine artery; N.C., nasal cavity. Own collection, same embryo as figs. 4 and 5.

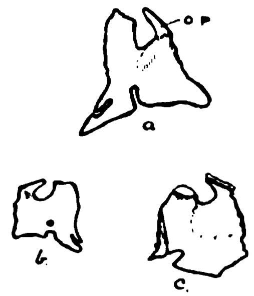

FIG. 7.

a, seven-month palate bone showing small orbital process; *b*, younger palate bone than *a*, and showing a foramen in the vertical plate; *c*, showing groove for internal pterygoid plate.

3. The palatine process appears in the 24 mm. embryo, at which time the two halves of the palate have become horizontal.

4. The orbital and sphenoidal processes are outgrowths from the vertical plate, and appear much later. Since the above was written, I have had evidence that the whole of the orbital process may not be formed by upward extension from the vertical plate. As in one specimen of the 2nd–3rd year, the orbital process of the right palate bone has a fissure running right through it at the junction of the lower $\frac{1}{3}$ with the upper $\frac{2}{3}$. This fissure separated off a small mass which synostosed behind with the body of the sphenoid and the sphenoidal turburated bone and in front with the ethmoid. On the opposite side the corresponding mass was fused with the ethmoid, the orbital process of the palate bone was small, whereas the lateral mass of the ethmoid was much longer on that side than the other.

If we regard this mass as the epiphysis which Rambaud and Renault have described, then it raises the interesting question as to what is its morphological position. That point, I think, may well be deferred for a later paper on the question. See fig. 8.

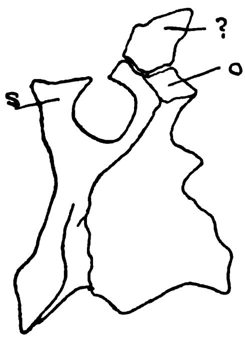

FIG. 8.—Three-year old palate bone, showing a separate mass (?) over orbital process O.

5. The sphenoidal process is throughout fœtal life larger than the orbital one.

6. Up to, say, about the second or third year, the antero-posterior length is greater than the vertical height of the palate bone.

7. The groove for articulation with the internal pterygoid plate is enormously larger than the other grooves on the tuberosity.

8. Chronologically the palate bone appears after the upper jaw, and is therefore third in date of appearance of the skull bones.

AN ABNORMAL VERMIFORM APPENDIX IN THE RABBIT. By

C. GORDON HEWITT, B.Sc., *Zoological Laboratory, The University, Manchester.*

WHILST demonstrating the abdominal viscera of one of the rabbits which were being dissected by the students in the elementary course of zoology, I discovered a very abnormal vermiform appendix.

An abnormal vermiform appendix of the rabbit. Natural size.

It is of the form shown in the accompanying figure. The proximal portion is a direct continuation of the cæcum, in the same line, and measures 35 mm. It then bends at right angles to the original direction, and this distal portion is 65 mm. in length.

Immediately after the bend a secondary appendix is given off. This is 60 mm. long and lies alongside the original appendix, by turning at right angles immediately after its origin.

The whole appendix was quite healthy in appearance, both externally and internally: there was nothing pathological about it.

On making a sagittal section of the structure, I found that the cavity of the secondary diverticulum was continuous with that of the original, as one would expect from the external appearance. The adjacent walls of the two appendices were quite separate, and only connected by the investing layer of connective tissue.

ON A SPECIMEN OF THE HIND-GUT OPENING INTO A CLOACAL CHAMBER IN A CHILD. By F. S. MACKENZIE, M.B., Ch.B., with a Note by Professor ARTHUR ROBINSON.

THIS specimen was removed from a female child aged one year and eleven months, who had suffered from alternating attacks of diarrhœa and constipation since birth. The child first came under notice as a patient in the County Hospital, York, in December 1904, when fourteen months old. She was then thin and wasted, with a distended abdomen in which could be

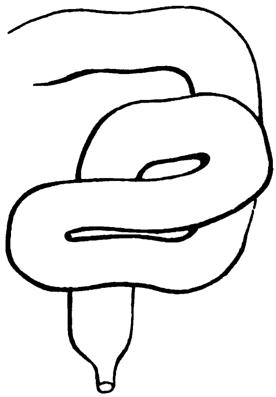

FIG. 1.

felt many solid fæcal masses varying in size from that of a walnut to a small Tangerine orange. A few days later she was removed by her parents, and remained at home until her death on September 25, 1905.

Permission for an autopsy was obtained with difficulty, but eventually objections were overcome and the body was then hardened with formalin before removal of the abdomen and pelvis *en masse*.

With the exception of the intestinal canal, no gross abnormalities were present other than a very marked hypertrophy and dilatation of both ureters.

The greater part of the abdomen was occupied by the enormously distended and hypertrophied large intestine, which was full of faceted masses of hardened fæces. The coils of this portion of the canal were arranged as in the accompanying diagram (fig. 1), and had displaced the greater portion of the small intestine into various holes and corners, while the transverse

colon had rotated the stomach round a transverse axis so that the pyloric end lay immediately in front of the termination of the œsophagus.

A saggital section was made through the lower half of the abdomen and pelvis, and the termination of the intestinal canal into the posterior portion of the vulva displayed, as is well seen in the illustration (fig. 2).

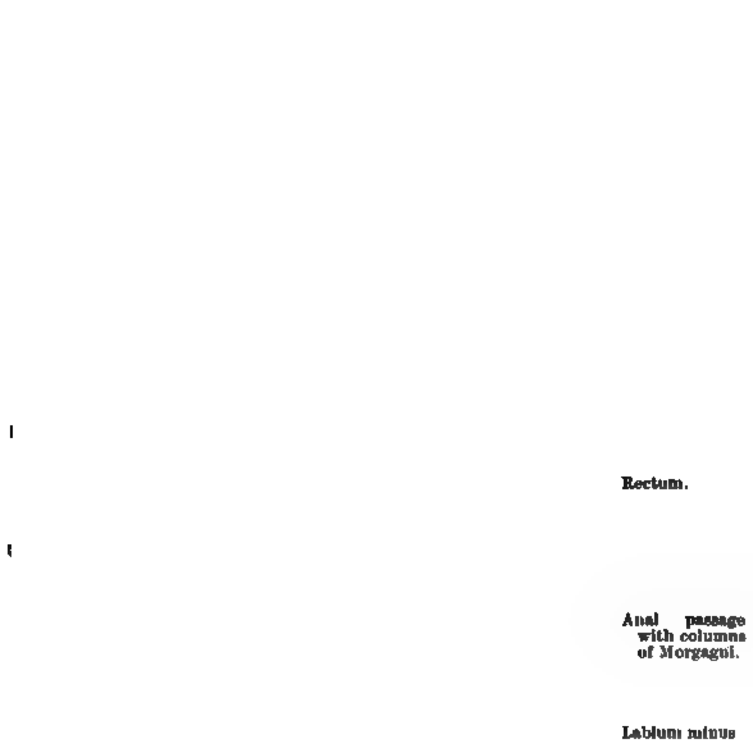

Fig. 2.

The rectum itself will be observed as quite distinct from the well-marked anal canal, while there is nothing between the latter and the sacrum to indicate any attempted formation of an anus in the usual situation.

The uterus having been diverted somewhat to the right side, is not seen in section, but the vagina, bladder, and urethra are quite distinct.

The specimen was forwarded to Professor Robinson, to whom I am much indebted for permission to publish the following note:—

"The specimen is one of considerable interest in connection with the development of the hinder part of the gut.

"The lower part of the great gut is separated into two portions by a very distinct constriction. The upper or rectal portion is devoid of rectal folds or valves. In the lower portion or anal passage the mucous membrane presents well-marked vertical folds—the columns of Morgagni—which commence above in the upper margin of the lip which separates the anal passage from the rectum, and terminate below in a reticulum of small folds immediately above the anal orifice.

"The anal passage runs, not in the normal direction, downwards and backwards, but downwards and forwards, and the anal orifice opens into a chamber common to it, the vagina and the urethra; that is, the anal passage opens, not on the surface behind the genito-urinary chamber, but into a cloaca.

"The cloacal chamber has no great vertical height, but it is quite distinct, and its orifice is bounded by the bases or upper margins of the labia minora; therefore the urethra, vagina, and anal passage still open, as in the young embryo, into a common entodermal cloaca, but with the difference that the genital and urinary canals are entirely separate from each other.

"In the ordinary course of events the gut would be separated from the genito-urinary canal before the latter gained an opening into the external or ectodermal cloacal depression. For a time after this separation occurs the gut ends blindly; at a later period it opens by a new opening into the posterior part of the external cloacal depression or proctodæum, which in the meantime has been separated from the anterior or genito-urinary part, by a transverse fold.

"In the specimen now under consideration, the internal or entodermal cloacal chamber has never been separated into two parts; that is, the internal or entodermal cloaca has persisted and has opened into the anterior part of the external cloacal depression, and the posterior part of that depression, if it existed, has disappeared, no trace of a proctodæal depression being discoverable.

"That the anal orifice is not merely a proctodæal opening displaced forwards but still opening into the external cloacal depression, is shown by its position above the bases of the labia minora.

"So far as the specimen can be taken as evidence of ordinary development, it shows that the anal passage is a part of the primitive hind-gut, and is not formed from the proctodæal depression. It entirely supports the view of the development of the posterior part of the gut so generally held and so forcibly demonstrated by Keibel's observations, and the evidence it furnishes is absolutely opposed to the suggestion that the posterior end of the gut is a backgrowth beyond the bond of union between the gut proper and the genito-urinary chamber."

In conclusion, I may state that one half of the section is in the museum of the University of Birmingham, and the other in the University of Leeds.

A RECORD OF THE DECUSSATIONS OF THE BRACHIAL PLEXUS IN MAN. By SYDNEY SCOTT, M.S. LOND., F.R.C.S. ENG., *St Bartholomew's Hospital.*

THIS paper is based on dissections of the decussating fibres of the brachial plexus. Twenty-five cases were examined, of which 17 were adult and 8 fœtuses. The estimated ages of the fœtuses were 3½, 4½, 5½, 6, and 9 months respectively.

MAIN CONCLUSIONS. (Fig. 1.)

The brachial nerves are derived from the anterior primary divisions of the 5th, 6th, 7th, 8th cervical, and 1st dorsal spinal nerves, the anterior roots of which contain fewer fasciculi than the posterior, the proportion

FIG. 1.

being one-third to one-half. The anterior primary divisions of the 5th and 6th unite, decussate, and divide into three parts: anterior, which forms the chief part of the musculo-cutaneous; the middle, which forms the suprascapular; and the posterior, which forms the circumflex and a small part of the musculo-spiral. The anterior primary division of the 7th nerve divides into anterior and posterior parts: the anterior becomes the outer head of the median, running for a varying distance with the musculo-cutaneous, and the posterior, which forms the main part of the musculo-spiral. The anterior primary division of the 8th and 1st dorsal nerves unite and then divide into three parts: the anterior, which forms the inner head of the median; the middle, which forms the ulnar and the internal cutaneous; and the posterior, which is the smallest, and derived from the 8th only, and enters into the composition of the musculo-spiral.

DECUSSATION "A." 20 Records. (Fig. 2.)

The decussations of the 5th and 6th cervical nerves: the arrangement was that shown in fig. 2 (with one exception, in which no fibres could be traced from the 6th nerve to the suprascapular). In these cases the

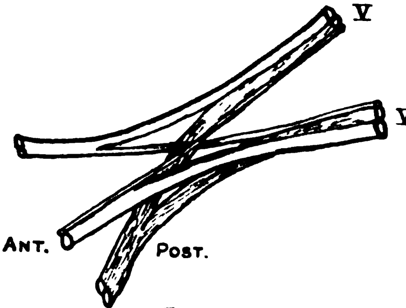

FIG. 2.

anterior primary divisions of the 5th and 6th nerves were each divisible into three main fasciculi: of these the uppermost fasciculus of each nerve united to form the suprascapular nerve, the intermediate fasciculi united to form the posterior secondary division which eventually became the circumflex, the lowest fasciculi united and eventually became the musculo-cutaneous. The relative size of the fasciculi was found to be remarkably constant. The uppermost fasciculus of the 5th and the lowest fasciculus of the 6th were in each case the largest of the three fasciculi in each nerve; and conversely the lowest fasciculus of the 5th and the uppermost fasciculus of the 6th were the smallest; while the intermediate fasciculus of the 5th and that of the 6th were intermediate in size. Again, the lowest bundle of the 5th passed to the lowest bundle of the 6th in front of the upper bundle

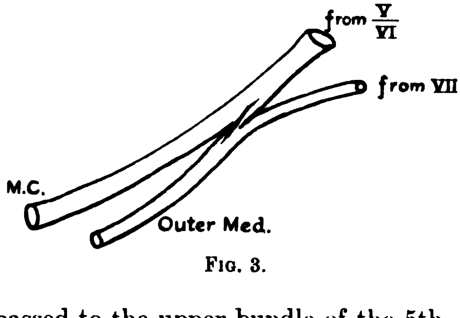

FIG. 3.

of the 6th, which passed to the upper bundle of the 5th. The intermediate bundles united posteriorly and were approximately of equal size, the fasciculus from the 6th never being smaller than that from the 5th.

DECUSSATION "B." 20 Records. (Fig. 3.)

The anterior secondary division of the 5th, 6th, and 7th nerves exhibit comparatively few decussating fibres. In only four could a well-formed fasciculus be traced from the 7th nerve to the musculo-cutaneous. In only three could a well-formed fasciculus be traced from the "5th, 6th" to the outer head of the median. In the other cases the interchange of fibres was frail, and represented by a few fine filaments.

DECUSSATION "C." 17 Records. (Fig. 4.)

This decussation takes place between the posterior secondary divisions of the "5th, 6th," 7th, and 8th cervical nerves. Of 17 dissections of this decussation, the greater part of the "5th, 6th" fibres were traceable into and formed the entire part of the circumflex nerve. In 13 cases a definite contribution was made by the "5th, 6th" to the 7th nerve, and

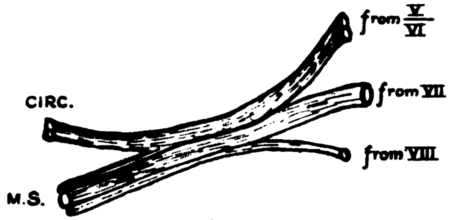

FIG. 4.

formed the uppermost bundle of the musculo-spiral. In four cases no fasciculus could be traced from the "5th, 6th" to the musculo-spiral nerve. As regards the posterior secondary division of the 8th, this was the smallest of the secondary divisions, and on joining that of the 7th it was traceable down the musculo-spiral as the lowest, *i.e.* as the innermost fasciculus of that nerve.

DECUSSATION "D." 8 Records. (Fig. 5.)

Of those fibres which formed the inner head of the median, approximately two-thirds were derived from the 8th cervical, and the remaining third from the 1st dorsal nerve. In one case no fibres could be traced into the median from the 1st dorsal, and in two cases half the inner head of the median was derived from the 8th cervical, and half from the 1st dorsal nerve. The internal cutaneous received more fibres from the 1st dorsal than from the 8th cervical nerve.

The ulnar nerve was derived about equally from the 8th cervical and the 1st dorsal nerves.

In one case the ulnar received about a sixth of its fibres from the 7th nerve, through the anterior secondary division of the 7th. This latter case was associated with a short cervical rib, which passed behind and above

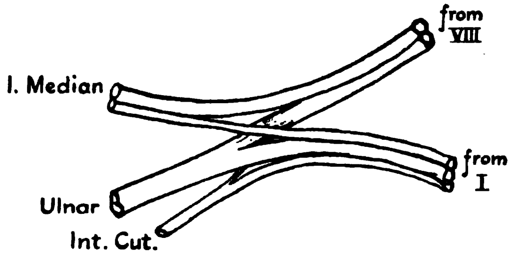

Fig. 5.

the axillary artery, and terminated in the scalenus medius about an inch above the first thoracic rib.

In this case the branch from the 7th to the ulnar arose from the anterior secondary division of the 7th, passed obliquely across the front of the axillary artery behind the inner head of the median, and formed the upper, *i.e.* the outer part of the ulnar nerve.

Table of Summary of Results. (After Herringham).

Spinal Nerves.	4.	5.	6.	7.	8.	1.
Scalenus anticus			+			
To phrenic	+					
Posterior thoracic		+	+	+		
Suprascapular		+ +	+			
Outer cord—						
External anterior thoracic			+	+		
To coracobrachialis			+	+		
Musculo-cutaneous		+	+ +			
Outer head of median			+	+ +		
Inner cord—						
Internal anterior thoracic					+	
Internal cutaneous					+	+ +
Ulnar					+	+
Inner head of median					+ +	+
Posterior cord—						
Short subscapular		+	+			
Long subscapular				+		
Lowest subscapular		+	+			
Circumflex		+	+			
Musculo-spiral			+	+ +	+	

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